HAZARD CLASS DEFINITIONS

CLASS 1 - EXPLOSIVES

Definition

Class 1 comprises:

(a) explosive substances, except those whose predominant hazard should be in another class;

(b) explosive articles, except devices containing explosive substances in such a limited quantity or of such a character that their inadvertent or accidental ignition or initiation, during transport, will not cause any manifestation of projection, fire, smoke, heat or loud noise external to the device; and

(c) articles and substances not mentioned above which are manufactured with a view to producing a practical explosive or pyrotechnic effect

To be considered for air transport, the purity, stability, sensitivity (including sensitivity to vibration, temperature cycling and pressure variation) and other physical properties of all explosives, whether or not contained in a contrivance, must comply with these Regulations.

A "new explosive article or substances" is considered to be any of the following:

- a new explosive substance, or combination or mixture of explosive substances, which is significantly different from substances or mixtures previously approved; of each of these compatibility groups together with the hazard groups which contain articles and/or substances of the group.
- a new design of an explosive article, or an article containing a new explosive substance or a new combination or mixture of explosive substances;
- a new design of package for an explosive article or substance including a new type of inner packaging.

Class 1 is divided into six divisions:

Division 1 - Articles and substances having a mass explosion hazard.

Division 2 - Articles and substances having a projection hazard but not a mass explosion hazard.

Division 3 - Articles and substances having a fire hazard and either a minor blast hazard or both, but not a mass explosion hazard. This division comprises articles and substances that:

- give rise to considerable radiant heat, or
- burn one after another, producing minor blast and/or projection effects.

Division 4 - Articles and substances having no significant hazard (only a small hazard) in the event of ignition or initiation during transport. The effects are largely confined to the package and no project of fragments of appreciable size or range is to be expected. An external fire must not cause practically instantaneous explosion of virtually the entire contents of the package.

Articles and substances in this division are in Compatibility Group S when they are so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package; if the package has been degraded by fire, all blast or projection effects are limited to the extent that they do not significantly hinder fire-fighting or other emergency response efforts in the immediate vicinity of the package.

Division 5 - Very insensitive substances, having a mass explosion hazard, which are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport. As a minimum requirement they must not explode in the fire test.

Division 6 - Extremely insensitive articles which do not have a mass explosion hazard.

This division comprises articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation.

CLASS 2 - GASES

Definition

A gas is a substance which:

- at 50°C (122°F) has a vapour pressure greater than 300 kPa (3.0 bar, 43.5 lb/in^2); or
- is completely gaseous at 20°C (68°F) at a standard pressure of 101.3 kPa (1.01 bar, 14.7 lb/in^2)

The transport condition of a gas is described according to its physical state as:

- Compressed gas - a gas (other than in solution) which, when packaged under pressure for transport, is entirely gaseous at 20°C (68°F);
- Liquefied gas - a gas which, when packaged for transport, is partially liquid at 20°C (68°F);
- Refrigerated liquefied gas - a gas which, when packaged for transport, is partially liquid because of its low temperature;
- Gas in solution - compressed gas, which when packaged for transport, is dissolved in a solvent.

Class 2 gases are assigned to one of three divisions based on the primary hazard of the gas during transport:

Division 1 - Flammable gas: Gases which at 20°C (68°F) and a standard pressure of 101.3 kPa (1.01 bar, 14.7 lb/in^2):

- are ignitable when in a mixture of 13% or less by volume with air; or
- have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit. Flammability must be determined by tests or by calculation in accordance with methods adopted by ISO (see ISO Standard 10156:1990). Where insufficient data are available to use these methods, tests by a comparable method recognized by the appropriate national authority must be used.

Division 2 - Non-flammable, non-toxic gas: Gases which are transported at a pressure not less than 280 kPa at 20°C, or as refrigerated liquids, and which;

- are asphyxiant - gases which dilute or replace the oxygen normally in the atmosphere; or
- are oxidizing - gases which may, generally be providing oxygen, cause or contribute to the combustion of other material more than air does; or
- do not come under the other divisions.

Division 3 - Toxic gas: Gases which

- are known to be so toxic or corrosive to humans as to pose a hazard to health; or
- are presumed to be toxic or corrosive to humans because they have an LC_{50} value equal to or less than 5000 mL/m^3 (ppm) when tested.

Note: Gases meeting the above criteria owing to their corrosivity are to be classified as toxic with a subsidiary corrosive risk.

Class 2 also includes "aerosols." For the purpose of these regulations, an aerosol means any non-refillable receptacle made of metal, glass or plastic and containing a gas compressed, liquefied or dissolved under pressure, with or without a liquid, paste or powder, and fitted with a self-closing release device allowing the contents to be ejected as solid or liquid particles in suspension in a gas, as a foam, paste or powder, or in a liquid or gaseous state.

CLASS 3 - FLAMMABLE LIQUIDS

Definition

This class has no subdivisions. It comprises liquids or mixtures of liquids or liquids containing solids in solution in suspension which give off a flammable vapour at temperatures of not more than 60.5°C (141°F) closed-cup test or not more than 65.6°C (150°F) open-cup test.

Flammable liquids are assigned to packing groups according to the flash point and the boiling point of the liquid.

Viscous flammable substances, such as paints, varnishes, enamels, lacquers, adhesives and polishes, having a flash point below 23°C (73°F) are normally assigned to Packing Group II but they may be assigned to Packing Group III by taking the following criteria into consideration:

- the closed-cup flash point;
- the viscosity expressed as the flow time in seconds;
- a solvent separation test;
- the size of the receptacle; and
- the presence of other hazards.

CLASS 4 - FLAMMABLE SOLIDS; SUBSTANCES LIABLE TO SPONTANEOUS COMBUSTION; SUBSTANCES WHICH, IN CONTACT WITH WATER, EMIT FLAMMABLE GASES

Class 4 is divided into three divisions as follows:

Division 1 - Flammable solids

Definition: Flammable solids. Solids which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction; self-reactive and related substances which are liable to undergo a strongly exothermic reaction; desensitized explosives which may explode if not diluted sufficiently. Division 1 contains:

- flammable solids;
- self-reactive and related substances;
- desensitized explosives.

Flammable solids are readily combustible solids and solids which may cause fire through friction. Readily combustible solids are powdered, granular or pasty substances which are dangerous if they can be easily ignited by brief contact with an ignition source, such as a burning match, and if the flame spreads rapidly. The danger may not only come from the fire but also from toxic combustion products. Metal powders are especially dangerous because of the difficulty of extinguishing a fire since normal extinguishing agents such as carbon dioxide or water can increase the hazard.

Division 2 - Substances liable to spontaneous combustion

Definition: Substances liable to spontaneous combustion. Substances which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up in contact with air, and being then liable to catch fire.

Two types of substances can be distinguished with spontaneous combustion properties:

- Pyrophoric substances - substances (liquid or solid) including mixtures and solutions which, even in small quantities, ignite within 5 minutes of coming in contact with air. These substances are the most liable to spontaneous combustion;

- Self-heating substances - solid substances which generate heat when in contact with air without an additional energy supply. These substances will ignite only in large amounts (kilograms) and after long periods of time (hours or days).

Division 3 - Substances which, in contact with water, emit flammable gases (Dangerous when wet.)

Definition: Substances which, in contact with water, emit flammable gases (Dangerous when wet.) Substances which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

CLASS 5 - OXIDIZING SUBSTANCES AND ORGANIC PEROXIDES

Class 5 is divided into two divisions:

Division 1 - Oxidizing substances are substances which, in themselves are not necessarily combustible, but may generally cause or contribute to the combustion of other material by yielding oxygen.

Division 2 - This division is made up of organic substances which contain the bivalent structure -O-O- and may be considered derivatives of hydrogen peroxide in which one or both the hydrogen atoms have been replaced by organic radicals.

Note: Hydrogen peroxide is made up of two hydrogen atoms and two oxygen atoms connected in a chain thusly: H-O-O-H.

Organic peroxides are thermally unstable substances which may undergo exothermic, self-accelerating decomposition. In addition, they may have one or more of the following properties:

- be liable to explosive decomposition;
- burn rapidly;
- be sensitive to impact or friction;
- react dangerously with other substances;
- cause damage to the eyes.

CLASS 6 - POISONOUS (TOXIC) AND INFECTIOUS SUBSTANCES

Class 6 is divided into two divisions as follows:

Division 1 - Poisonous (toxic) substances are substances which are liable to cause death or injury or to harm human health if swallowed, inhaled or contacted by the skin.

Poisonous substances, including pesticides, must be assigned to packing groups referred according to the degree of their toxic hazards in transport. In assigning the packing group, account has been taken of human experience in instances of accidental poisoning, and of special properties possessed by an individual substance, such as liquid state, high volatility, any special likelihood of penetration, and special biological effects. In the absence of human experience the grouping has been based on the available data from animal experiments. When a substance exhibits a different order of toxicity by two or more routes of administration, the highest degree of toxicity must be used to assign the packing group. When a substance exhibits a different order of toxicity by inhalation of mists and by inhalation of vapours, the highest degree of toxicity must be used to assign the packing group.

Liquids having a vapour inhalation toxicity of Packing Group I are forbidden on both passenger and cargo aircraft.

Note: In these regulations "toxic" has the same meaning as "poisonous."

Division 2 - Infectious Substances. Substances containing viable micro-organisms including a bacterium, virus, rickettsia, parasite, fungus, or a recombinant, hybrid or mutant, that are known or reasonably believed to cause disease in animals or humans.

- Biological products - Those substances which meet one of the following criteria:
  - finished biological products for human or veterinary use manufactured in accordance with the requirements of national public health authorities and moving under special approval or license from such authorities;
  - finished biological products shipped prior to licensing for development or investigational purposes for use in humans or animals;
  - finished biological products for experimental treatment of animals, and which are manufactured in compliance with the requirements of national public health authorities.

CLASS 7 - RADIOACTIVE MATERIAL

For the purposes of these regulations, a radioactive material is any article or substance with a specific activity greater than 70 kBq/kg (0.002 μCi/g).

CLASS 8 - CORROSIVES

Definition: Substances which, in the event of leakage, can cause severe damage by chemical action when in contact with living tissue or can materially damage other freight or the means of transport.

The test criteria for the three packing groups in this class are:

- Packing Group I - (substances presenting great danger) - substances that cause visible necrosis of the skin tissue at the site of contact when tested on the intact skin of an animal for a period of three minutes or less;

- Packing Group II - (substances presenting medium danger) - substances that cause visible necrosis of the skin tissue at the site of contact when tested on the intact skin of an animal for a period of more than 3 but not more than 60 minutes;

- Packing Group III - (substances presenting minor danger) - substances that cause visible necrosis of the skin tissue at the site of contact when tested on the intact skin of an animal for a period of more than 60 minutes but less than four hours, or substances which are judged not to cause visible necrosis in human skin but which exhibit a corrosion rate on steel or aluminum surfaces exceeding 6.25 mm a year at a test temperature of 55°C (130°F).

CLASS 9 - MISCELLANEOUS DANGEROUS GOODS

Definition: Substances and articles which during air transport present a danger not covered by other classes. Included in this class are: Other regulated substances, Magnetized material and miscellaneous articles and substances.

Other Regulated Substances: A liquid or solid which has anaesthetic, noxious or other similar properties which could cause extreme annoyance or discomfort to passengers and/or flight crew members.

Magnetized Material: Any material which, when packed for air transport, has a magnetic field strength of 1.59 A/m (0.002 gauss) or more at a distance of 2.1 m (7 ft) from any point on the surface of the assembled package (see also Packing Instruction 902, which includes methods of determining magnetic field strength).

Miscellaneous articles and substances:

- Asbestos
- Dry-Ice
- Environmentally hazardous substances
- Life-saving appliances
- Engines, internal combustion
- Polymeric beads
- Battery-powered vehicles
- Wheelchair, electric
- Zinc dithionite.

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4a Express Package Service *Packages under 150 lbs.* Delivery commitment may be later in some areas
- [X] FedEx Priority Overnight (Next business morning)
- [ ] FedEx Standard Overnight (Next business afternoon)
- [ ] FedEx 2Day* (Second business day)
- [ ] FedEx Express Saver* (Third business day)
- [ ] FedEx First Overnight (Earliest next business morning delivery to select locations) (Higher rates apply)

*FedEx Letter Rate not available. Minimum charge: One pound rate

4b Express Freight Service *Packages over 150 lbs.* Delivery commitment may be later in some areas
- [ ] FedEx Overnight Freight (Next business day)
- [ ] FedEx 2Day Freight (Second business day)
- [ ] FedEx Express Saver Freight (Up to 3 business days)

(Call for delivery schedule. See back for detailed descriptions of freight services.)

5 Packaging
- [ ] FedEx Letter
- [ ] FedEx Pak
- [ ] FedEx Box
- [ ] FedEx Tube
- [X] Other Pkg

Declared value limit $500

6 Special Handling

Does this shipment contain dangerous goods?
- [ ] Yes (As per attached Shipper's Declaration)
- [ ] Yes (Shipper's Declaration not required)
- [ ] Dry Ice — Dry Ice, 9, UN 1845, III x kg 904 (Dangerous Goods Shipper's Declaration not required)
- CA [ ] Cargo Aircraft Only

7 Payment

Bill to:
- [X] Sender (Account no. in section 1 will be billed)
- [ ] Recipient
- [ ] Third Party
- [ ] Credit Card
- [ ] Cash/Check

(Enter FedEx account no. or Credit Card no. below)

FedEx Account No.

Credit Card No. Exp. Date

Total Packages	Total Weight	Total Declared Value*	Total Charges
		$ .00	$

*When declaring a value higher than $100 per shipment, you pay an additional charge. See SERVICE CONDITIONS, DECLARED VALUE, AND LIMIT OF LIABILITY section for further information.

8 Release Signature Sign to authorize delivery without obtaining signature

Your signature authorizes Federal Express to deliver this shipment without obtaining a signature and agrees to indemnify and hold harmless Federal Express from any resulting claims.

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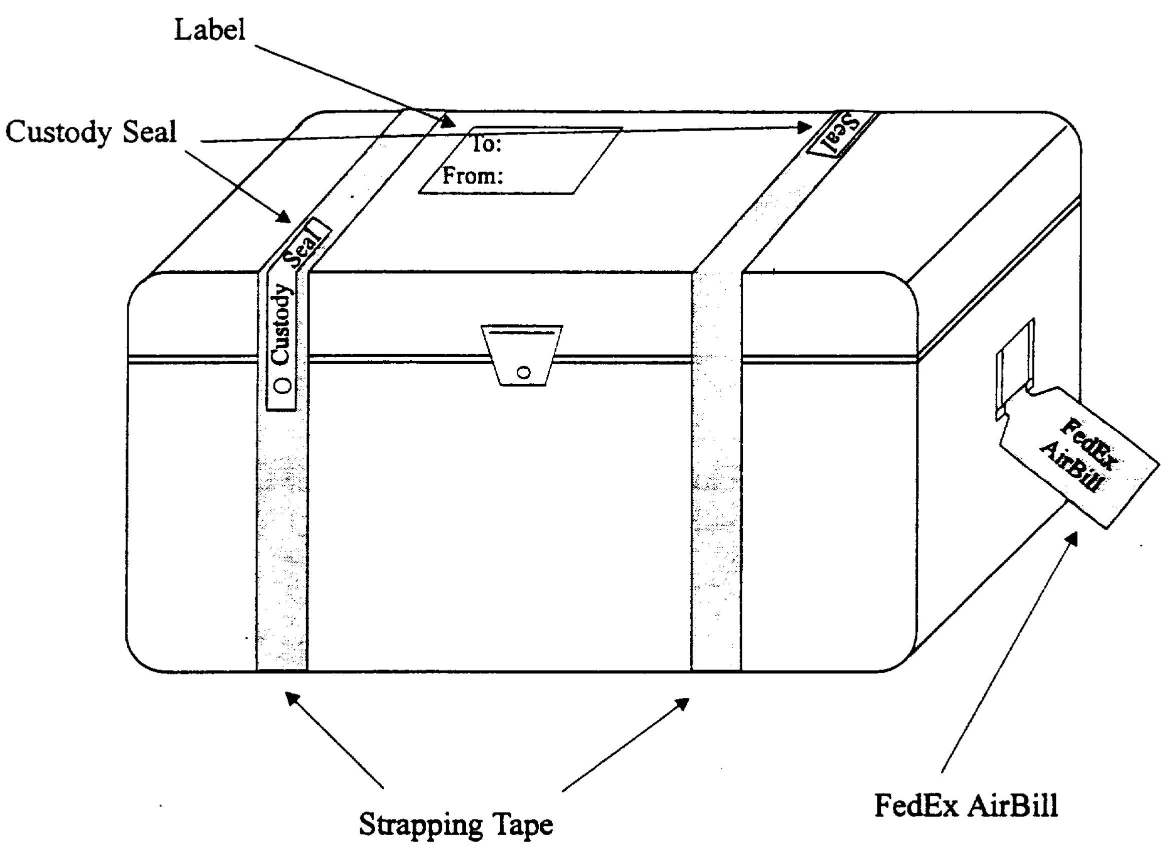
SOP Number: 04-02-00
DIAGRAM A

SAMPLE COOLER



Technical Approval: ______________________ Date: 4/29/99

QA Management Approval ______________________ Date: 6/21/99

SOP Description

This Standard Operating Procedure (SOP) describes the procedures to be followed by TechLaw staff when preparing a groundwater sampling and analysis plan (SAP) for commercial or government clients. Typically, these plans include, but are not limited to, discussions of the following activities: pre-sampling activities, well installation and well development, groundwater sampling (e.g., analytes, sample locations, number of samples, field parameter, etc.), decontamination of equipment, and well abandonment. Details regarding these and other groundwater sampling/monitoring and analysis procedures are presented in other SOPs included in the "06" series.

Many of the elements of a groundwater SAP discussed herein may also be addressed within a site-specific quality assurance project plan (QAPP), if applicable. The necessity for, and preparation of the QAPP should be discussed with the client to ensure that both documents, if required, contain the appropriate, or regulatorily required, information (e.g., EPA typically requires a QAPP, while some commercial clients, depending upon the purpose of the sampling activity, may not want the added expense associated with the development of an additional document).

When the sampling of groundwater, surface water, and/or soil is to be conducted at a site, a complete SAP can be written to specifically address all sampling activities. See SOP No. 07-01-XX for specific procedures for preparation of a soil/sediment SAP, and SOP No. 08-01-XX for a surface water SAP. If applicable, use the media specific SOP to assist in the development of an all-inclusive SAP.

General Procedures

Related SOPs

This SOP is to be used in conjunction with the other relevant or applicable SOPs found in the following SOP categories:

Section No.	Section Title
01	General Procedures
02	Field Procedures
03	Field Documentation Procedures
04	Packaging and Shipping Procedures
05	Field Equipment Operation and Maintenance Procedures
06	Groundwater Sampling/Monitoring and Analysis Procedures
09	Health and Safety Procedures
10	Regulatory Compliance Procedures
11	Quality Assurance Procedures

Related Documentation and Apparatus

The following documentation can be used in developing a groundwater SAP:

- QAPP, and
- Site hydrologic/geologic data and contaminant nature/occurrence information such as well logs and well completion information.

Sampling and Analysis Plan Development Procedures

The SAP must address those procedures key to obtaining representative groundwater samples and reliable, appropriate and legally defensible analytical data. The plan itself should include, at a minimum: title page, approval sheet, table of contents, introduction, analytical parameters and sampling locations, pre-field sampling activities, field sampling activities, field QA/QC, field documentation requirements, packaging and shipping requirements, chain-of-custody procedures, laboratory QA/QC, and the health and safety plan. These elements (with the exception of the title page, approval sheet, and table of contents) are discussed below, on a section-by-section basis. The format presented is typical of SAPs; and ensures that all necessary elements are discussed in a logical fashion.

Introduction

The introduction provides a brief overview of the facility and presents the purpose (rationale) and objectives for collecting samples at the site. Information contained in the introduction should include a physical description of the facility and surrounding lands, facility location map, a historical narrative outlining the events leading up to the proposed sampling activities, the proposed sampling locations and rationale for sample location selection, a sample location map, the proposed use of the data (i.e., Data Quality Objectives for the Project), and the general organization of the SAP.

Analytical Parameters and Sampling Locations

This section identifies and discusses information regarding the analytical parameters and sampling locations, and addresses the overall objectives of the sampling and analysis program. Tables may be included which provide: (1) the analytical test methods, container types, sample sizes, preservation methods, and holding times; and (2) the summary of the number of groundwater and QA/QC samples to be taken at each location. Alternately, if a QAPP is prepared for the project as well, direct reference in the SAP to the applicable QAPP Section and page numbers is adequate, and/or, direct reference to the TechLaw Quality Assurance Program Plan may be appropriate under certain government contracts.

- **Identification of Sampling Objectives** - In this section, the facility or property is described, including the area(s) to be sampled. Included in this section are the reason(s) for sampling and identification of any specific concerns (e.g., hazardous petroleum-based constituents leaking from underground storage tanks). Site plans identifying the proposed sampling location(s) are to be attached, including the location of proposed well installations and abandonments.

- **Data Quality Objectives** - The SAP must specify the Data Quality Objectives (DQOs) established for the project and how the DQOs will be met. DQOs are qualitative and quantitative statements which specify the quality of data required to support decisions during sampling activities. DQOs provide information on the limits of the data, which in turn, dictate the proper uses of the data. DQO levels are numbered I through IV with I being the lowest and IV the highest quality data. Higher quality methods may be substituted for lower-level work.

- **Sampling Numbers and Analytical Procedures** - The projected or required number of samples and analytical parameters for these samples are described in this section, including both environmental and background samples. Specific analytical parameters for each sample to be collected are also identified, as are descriptions of the analytical methods to be used. Due to the size of the analytical method descriptions, these are often appended to the SAP, although most are included in the QAPP. These method descriptions may include: scope and application; summary of method; interferences; apparatus and materials; reagents; sample collection, preservation, and handling procedures; quality control; method performance; and references. Detailed information pertinent to well installation and abandonment, including well location and sample collection procedures, should be included under a subsequent section.

- **Quality Control Samples** - In addition to the environmental and background samples identified above, information on the number and types of QC samples (e.g., field duplicates [1 per 10], equipment blanks [1 per 20], rinsate blanks [1 per 20], field rinsate blanks [1 per 20], trip blanks [1 per 20]) collected during the sampling event should be included. Information pertaining to QA/QC sample collection is presented in a later section, and should be detailed in the QAPP, if applicable.

- **Sample Collection Approach** - This section states how the daily sampling activities will proceed and justifies the selected approach (e.g., from the area of least expected contamination to the area of highest expected contamination).

Pre-Field Sampling Activities

This section provides a listing of the activities that the TechLaw field team leader and/or designee(s) must accomplish prior to commencement of field activities. They include the following:

- Verify that the client has received, and if appropriate has reviewed, approved, and signed off on the SAP.
- Notify the laboratory of the upcoming sampling event so that the laboratory can prepare the appropriate type and number of sample containers and schedule analysis time. This will be determined based on the list of parameters to be measured at each site, the number of sampling locations, and the number of QC samples.
- Collect, prepare and inspect all field equipment prior to use.
- Assemble all forms and documents to be used in the field (e.g., field logbook, chain-of-custody sheets, sample labels, sample tags [if applicable], sample seals).
- Conduct any other activity necessary to mobilize personnel to the site, including equipment necessary for drilling activities, if monitoring well installation or abandonment is required.

Field Sampling Activities

This section provides an outline of the various tasks required for sampling. Additionally, procedures for well installation and/or abandonment should be included or properly referenced, if applicable.

- **Preparation of Equipment and Supplies** - This section describes the equipment and supplies that will be supplied by the laboratory or provided/purchased as necessary for the field activity. As appropriate, indicate how the equipment is to be assembled, calibrated, and tested before it is shipped to the site.
- **Field Inspection of Equipment and Supplies** - This section describes how the equipment and supplies will be inventoried, checked for damage, and calibrated

once it arrives in the field. Notation is also made at this time that the field QA/QC protocol and the HASP have been reviewed.

- **Labeling of Containers** - This section indicates how containers will be labeled, prior to, during and following the sampling event in order to reduce confusion in the field. As appropriate, the required information will be written on the label or tag at the time the sample is collected and will be documented in the field notebook.

- **Site Safety and Work Zones** - This section is provided in conjunction with the HASP. It states who is responsible for delineating the working boundaries (i.e., exclusion zone, contamination reduction zone, support zone). It also designates the site health and safety officer (SHSO), who is responsible for implementation of the HASP, including determining the necessary levels of protection. This section may simply reference the specific section and/or page number where the appropriate information can be found in the HASP.

- **Location of Sampling Points** - This section describes how the field team will identify the sampling locations (i.e., wells, or well installation locations).

- **Monitoring Well Installation and Development or Abandonment** - This section provides all necessary information regarding the monitoring wells that will be installed, including location, completion intervals, drilling mechanisms, well materials, abandonment procedures, and a schematic diagram of the representative monitoring well (see SOP Nos. 06-02-XX and 06-05-XX, Well Installation and Development and Well Abandonment, for additional information). The SAP includes the number of well volumes that will be removed from each monitoring well, as well as recharging time prior to sample collection and disposition of purge/development water.

- **Groundwater Sampling** - This section includes information necessary to convey how groundwater samples will be collected. This should include water level measurement determination, the number of well volumes to be purged prior to sampling, the type of equipment to be used during purging and sampling, and how the samples will be handled. See SOP Nos. 06-03-XX and 06-04-XX, Pre-Sampling Activities and Sampling Activities, for additional information.

- **Decontamination Procedures** - This section describes the TechLaw's adherence to procedures for disassembly and cleaning of equipment and apparatus (see SOP No. 02-03-XX). The specific steps are included under Field QA/QC.

- **Preparation of Samples for Shipment** - This section describes the procedures for preparing the samples for shipment to the laboratory for analysis. It includes completion and affixing of the labels to the bottles, placement and applicability of custody seals, use of sample tags (if applicable), packing, use of blue ice/ice, completion of the chain-of-custody, custody seals, sealing of the coolers, overnight shipment, and notification of sample shipment/special instructions to the laboratory. See SOP Nos. 02-05-XX, 04-02-XX, 04-03-XX, 04-04-XX, and 04-05-XX for additional chain-of-custody and packaging and shipping information.

- **Disposal of Sampling Wastes** - This section describes how sampling-generated wastes (e.g., excess groundwater samples; preservative wastes; PPE - including tyvek suits, gloves, boot covers, paper towels and wipes; and decontamination solutions) will be managed for disposal at the sampling site. Refer to SOP No. 02-04-XX for additional information concerning the management of investigation-derived wastes.

Field QA/QC

This section provides detailed field QA/QC procedures to ensure the reliability of the data generated by the sample collection activities. The QAPP, if available, also addresses most of this information and should be referenced/appended.

- **Sample Collection Procedures** - This section provides the QA/QC procedures to be followed to ensure that samples are collected using accepted field techniques in a consistent manner. These methods should be consistent between sample locations and for all samples collected, ensuring that appropriate QA/QC procedures are used to enhance data quality.

- **Quality Control Sample Collection** - This section identifies the types of QC samples to be collected (e.g., field duplicate samples, equipment blanks, rinsate blanks, field blanks, and trip blanks), as well as the procedures to be used when collecting these samples.

- **Sample Containers** - This section describes the sample containers, supplier, and shipping protocols.

- **Equipment Decontamination** - This section provides the step-by-step procedures to decontaminate field equipment. Personnel decontamination procedures are provided in the HASP.

Field Documentation Requirements

This section of the SAP describes the procedures for documenting the field sampling activities. At a minimum, all field sampling activities and procedures must be recorded in the field logbook and documented through the collection of representative photographs. Additional documentation procedures may be used as required (e.g., sample log, sample management and custody procedures, equipment calibration log, site safety log). The SAP should clearly indicate what specific field documentation procedures will be used and how the resulting data will be managed. The SAP should also include a statement that where any deviation(s) from the approved SAP is (are) made, it (they) will be fully documented along with the justification for the deviation(s).

Laboratory QA/QC

A copy of the laboratory's QA/QC manual may be attached to the SAP, depending on the client for whom the SAP is prepared. For most government activities, this information is already included with the QAPP, or may be retained with the laboratory coordinator if further information is required. This section may also identify how the laboratory will ensure that specific QA protocols will be followed, including sampling points, audits of work, laboratory chain-of-custody, internal sample tracking, analytical data documentation, and instrument calibration procedures. Alternatively, direct reference to specific sections and page numbers within the QAPP are appropriate.

Site-Specific Health and Safety Plan

A site-specific HASP developed in conformance with TechLaw's Health and Safety Program and approved by the Health and Safety Director (HSD), may be included in or appended to the SAP. However, the HASP is not typically a "required" deliverable under the majority of government contracts, so inclusion with the SAP may not be required. Procedures for the development of the HASP can be found in SOP No. 09-02-XX.

Sign-Off and Approval

The SAP may be forwarded to the client prior to the conduct of the sampling activity, for sign-off and approval. If this activity is required, a client approval sheet, with appropriate signature, is included. The approval sheet also contains the signature of the TechLaw project manager.

Health and Safety

It is TechLaw's policy to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress which is consistent with OSHA and other applicable and appropriate established standards and requirements.

All field personnel will be provided with appropriate personal protective clothing and safety equipment. At a minimum, this will include a hardhat, hearing protection, full-face respirator, steel-toed safety shoes, and safety glasses. Personnel are required to inspect their PPE prior to entering any job site and replace any damaged items.

A site-specific health and safety checklist/plan must be developed by the field team leader or designee and approved by the TechLaw Health and Safety Director prior to implementation in the field. This checklist/plan must be reviewed with the TechLaw field team members prior to beginning work.

Any deviation(s) from an approved site-specific health and safety checklist/plan must be documented in the field logbook.

QA/QC

The TechLaw Project Manager or designee responsible for the preparation of the SAP must ensure that the document contains all of the appropriate elements discussed above (as appropriate) and conforms with all procedures outlined with other relevant or applicable TechLaw SOPs.

Attachments

None at this time.

References

TechLaw Inc., Field Equipment Manufacturer's Instruction Manuals Handbook, Winter 1995.

TechLaw Inc., Health and Safety Program, 1999.

TechLaw Inc., Quality Assurance Program Plan

U.S. Environmental Protection Agency, Sampling for Hazardous Materials, November 1984.

U.S. Environmental Protection Agency, Characterization of Hazardous Waste Sites - A Methods Manual, EPA/600/4-84/075, April 1985.

U.S. Environmental Protection Agency, Test Methods for Evaluating Solid Waste, SW-846, Volume II, Field Methods, Second Edition, 1986.

U.S. Environmental Protection Agency, RCRA Groundwater Monitoring Technical Enforcement Guidance Document, OSWER-9950.1, September 1986.

U.S. Environmental Protection Agency, A Compendium of Superfund Field Operations Methods, EPA/540/P-87/001, Washington, D.C., 1987.

U.S. Environmental Protection Agency, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), U.S. EPA Region IV Environmental Services Division, May, 1996.

U.S. Environmental Protection Agency, RCRA Ground-Water Monitoring: Draft Technical Guidance, EPA/530-R-93-001, November, 1992.

Technical Approval: ______ Date: 6/15/99

QA Management Approval: ______ Date: 5/10/99

I. SOP Description

This Standard Operating Procedure (SOP) describes the procedures and equipment to construct, install, and develop groundwater monitoring wells and piezometers. If a borehole is to be used as part of an initial groundwater investigation to obtain relatively undisturbed lithologic samples and will subsequently be used only as a piezometer to obtain only water-level measurements, it requires certain equipment and installation procedures. However, if the borehole is to function as part of a RCRA or CERCLA groundwater monitoring system from which groundwater quality samples are to be collected, analyzed, and statistically evaluated, considerable attention must be given to all aspects of well construction, installation, and development. In addition, following well installation, a well is developed to induce normal groundwater flow into the well screen representative of groundwater in the formation from which it is being withdrawn. This requires removal of all groundwater whose normal flow regime/water quality has been disrupted by the presence of the borehole.

The procedures described in this SOP are used to ensure that wells will be installed and developed to accomplish, at a minimum:

- Monitoring of a discrete hydrologic zone,
- Prevention of cross-contamination from the surface or between hydrologic zones,
- Collection of data that is representative of the aquifer system, and
- Characterization of the stratigraphic and structural environment.

This SOP provides information which can be used to design and install piezometers and monitoring wells, and to evaluate the adequacy of proposed monitoring wells and groundwater monitoring systems.

II. General Procedures

Related SOPs

This SOP is to be used in conjunction with other relevant or applicable SOPs found in the following SOP categories:

Section No.	Section Title
01	General Procedures
02	General Field Procedures
03	Field Documentation Procedures
04	Packaging and Shipping Procedures
05	Field Equipment Operation and Maintenance Procedures
06	Groundwater Sampling/Monitoring and Analysis Procedures
09	Health and Safety Procedures
10	Regulatory Compliance Procedures
11	Quality Assurance Procedures

Related Documentation

The following documents are to be used and/or maintained in conjunction with a well installation and development. Specific guidelines are presented in the individual SOPs.

- Field logbook
- Photographs
- Health and Safety Plan (HASP)
- Groundwater Sampling and Analysis Plan (SAP) and, if applicable, Quality Assurance Project Plan (QAPP)

Upon completing installation of the well, a copy of the well log maintained by the site geologist should be obtained, if possible, for the project files. If well installation oversight is being performed, the documentation listed above should also be maintained where possible.

III. Equipment and Apparatus

This section describes the different methods of drilling, installing, and developing wells and outlines the preferred materials to be used under varied field conditions. Typically, the driller provides the materials and equipment that are normally required for the work to be performed (e.g., drill rig, casing and screen, water truck, pumps, hoses, grout, hand tools). The specific well completion materials are normally specified in the well installation plan which should be provided to the drilling company prior to mobilization so that the specified installation materials are available.

Types of Drilling Equipment

Five different types of drilling equipment are presented, along with their recommended uses.

Hollow-Stem Auger: The hollow-stem auger is best suited for drilling in unconsolidated materials that do not contain large rock fragments or boulders. The auger size (diameter) is determined by the diameter of the monitoring well or piezometer to be installed and by the ability of the formation to maintain an open borehole, but typically has an 8-inch outer diameter. Formation sampling is accomplished from inside the hollow-stem auger with split-spoon samplers or Shelby tubes, or with a continuous sampling device (e.g., the CME continuous sampler), with the sampling tool advanced ahead of the auger to obtain an undisturbed sample. Hollow-stem auger drilling is generally limited to depths of less than 100 to 150 feet, and is typically used for shallow boring installation in unconsolidated material. The hollow-stem auger consists of a hollow, steel shaft (or stem), with a continuous, spiraled steel flight welded onto the outside of the shaft. The auger contains a cutting head (auger bit) at the base of the assembly. When rotated, the cutting head penetrates the formation and transports the soil cuttings up the auger flights in the annulus to the ground surface. A center plug can be inserted into the auger to prevent the soil cuttings from clogging the center of the shaft. When the desired drilling depth is reached, the center plug can be removed and the well screen and riser pipe can be lowered to the appropriate completion depth inside of the auger's hollow shaft.

Solid-Stem Auger: The solid-stem auger consists of a solid stem (or shaft) with a continuous spiraled steel flight welded to the exterior of the stem. The base of the stem contains a cutting head (auger bit). When the assembly is rotated, the cutting head penetrates the formation and transports the soil cuttings up the auger flights to the ground surface. Since the stem is solid, the assembly must be removed from the borehole before the well screen and riser pipe can be set. The solid-stem auger is best suited for drilling in cohesive formations which do not have the tendency to collapse, and is more typically used to install boreholes above the water table, with alternative well installation methods used below this depth. The solid-stem auger is often used for drilling pilot holes that are subsequently enlarged with larger diameter hollow-stem augers and for reaming boreholes prior to abandonment. Specific procedures for well abandonment can be found in SOP No. 06-05-XX. Formation sampling can only be accomplished by removing the solid-stem auger from the borehole. Drilling depths are generally limited to 150 feet or less.

Air Rotary: The air rotary system consists of a drill bit which is attached to the base of hollow drill rods. The drill bits are typically roller-cone or tri-cone, and contain hardened steel teeth or carbide buttons. As the assembly is rotated, the bit penetrates the formation and grinds the soil or rock into cuttings. Compressed air is forced down the center of the drill pipe and out through small holes in the bit. The circulating air serves to cool the bit and force the drill cuttings up the annular space and out the borehole. Formation samples are collected from the cuttings. Since the air and cuttings exit the borehole at a high velocity, the cuttings and dust can settle out on the ground surface covering a relatively large area (several hundred square feet), which is problematic if the boring is installed in an area of contamination. Water is often added to the air stream to control the excessive dust. Dust and cuttings can be controlled by the use of a cyclone velocity dissipator, or other cutting containment system. In addition, EPA requires that an organic filter be added to the compressed air system to prevent the introduction of organic contaminants to the subsurface. The air rotary system is capable of drilling to thousands of feet in depth at a relatively high penetration rate. Depending upon the well depth, a larger diameter surface casing is often installed in the unconsolidated overburden prior to drilling into bedrock, to insolate shallower, water-bearing intervals. This method is best suited for use in hard rock (EPA, 1992). However, this technique should be used with caution during environmental investigations because, for example, it could jeopardize the collection of representative and accurate chemical data.

Air Hammer: The air hammer method, also called "down-the-hole hammer," is a variation of the air-rotary method by which drilling is accomplished by a slowly rotating bit that rapidly strikes or hammers the formation into fragments. The compressed air, which is used to cool the bit and lift the cuttings to ground surface, is also used to actuate and operate the pneumatic air hammer. Compressed air requirements for the hammer may range from 100 to 350 pounds per square inch. The formation is penetrated by the cutting and pounding action of tungsten carbide buttons on the bit face. The air hammer must be used with caution because oil is required in the air stream to lubricate the hammer-actuating device, which could potentially contaminate the formation and compromise ground-water sample quality. (EPA has indicated that only potable water should be used as a lubricant.) The air hammer is efficient in penetrating dense, hard rocks, including granite and basalt. Penetration rates in many formations are higher than for other drilling methods. Sampling and depth capabilities are comparable to the conventional air rotary drilling method.

Water/Mud Rotary: Water and mud rotary techniques are similar to the air drilling method with the exception that water or drilling mud (water containing additives such as bentonite and viscosifiers) is used to cool the drill bit and circulate cuttings instead of compressed air. The water or drilling mud is pumped down the center of the drill rods and out the bit, where it carries drill cuttings up the annular space to ground surface. The circulating water (or drilling mud) exits the borehole at the surface and flows across a screen to collect cuttings prior to flow into a mud pit, where additional cuttings settle out. From the mud pit, the water (or mud) is recirculated back down the borehole. Water rotary drilling is preferred to mud rotary for installation of groundwater monitoring wells because only potable water is used as the drilling fluid. In addition, the water does not clog the formation with solids (e.g., bentonite clay). On the other hand, water does not have the ability to stabilize the borehole as effectively as drilling mud, and flowing or heaving sands can usually be controlled only with drilling mud. If drilling mud must be used due to borehole instability problems, a high solids, polymer-free drilling fluid additive should be used. Pure bentonite can be used, as well as several new drilling fluid additives formulated specifically for the monitoring well industry. Products which may be considered include Pure Gold Gel and Volclay drilling fluids, both manufactured by American Colloid. However, many viscosifiers (e.g., QUIK-GEL, manufactured by Baroid) are not approved for use in monitoring wells. Total depths reached via the water and mud rotary method are limited only by the competency and stability of the borehole, and boreholes in excess of 10,000 feet are often installed using this technique in the oil and gas industry.

Cable Tool: Cable tool drilling rigs operate by repeated lifting and dropping of a heavy drill string into the borehole. The drill bit loosens material in unconsolidated formations and crushes consolidated rock into small fragments. Formation particles are mixed with water to form a slurry or sludge at the bottom of the borehole, which is periodically removed using a sand pump or bailer. There is a direct correlation between borehole depth and diameter using this technique, with smaller-diameter holes typically reaching greater depths. EPA (1992) states that this method will not work in consolidated bedrock (although experience has shown this not to be the case universally), and boreholes installed in unconsolidated sediments via cable tool normally require casing be installed following the bit to prevent caving. Cable-tool drilling is a preferred method for drilling coarse glacial till, boulder deposits, or rock strata that are highly fractured, jointed, or cavernous. Cable-tool drilling also allows identification of thin or low-yield aquifers that might be overlooked using other drilling methods. Wells can be constructed with little chance of contamination where little make-up water is used. Geologic samples may be collected at any interval unless heaving conditions occur. However, penetration rates are typically slow, and PVC and Teflon® casing generally cannot be installed using this technique due to potential casing damage during advancement into the hole. In addition, equipment availability is limited in certain areas, principally the southeastern and southwestern sections of the United States. Cable tools are capable of drilling wells to depths between 300 and 5,000 feet.

Well Construction Materials

This section lists the materials and components typically required for well installations, and describes the specifications for these materials.

Casing: For monitoring wells, stainless steel (ASTM Type 304 or 316) or Teflon®, two-inch minimum inside diameter, threaded, flush-jointed pipe is most commonly used.[1] Also, Polyvinyl chloride (PVC), Schedule 40, 2-inch minimum inside diameter, threaded, flush-jointed pipe, which complies with ASTM standard (F480-76(4.3) is commonly used for monitoring wells.

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[1] The U.S. EPA RCRA Ground-Water Monitoring: Draft Technical Guidance (EPA, 1992) indicates that well casing material should be selected based upon the strength-related and chemical characteristics of the material and site-specific demands. EPA (1992) indicates that Teflon® and stainless steel are the "first choice" completion materials for monitoring wells with metals and organic groundwater contamination, respectively, although PVC may be used as a second choice. In cases where both metal and organic groundwater contamination are present, neither stainless steel or Teflon® is recommended as a first choice, although PVC (and Teflon®, if no PCE is present) can be used as an alternative. The PVC casing must be Schedule 40, 2-inch minimum inside diameter, threaded, flush-jointed pipe which complies with ASTM Standard F480-76 (4.3) for PVC well casing. PVC glue should not be used.

PVC is also typically the construction material of choice for piezometers.[2]

Well Screens: For monitoring wells, stainless steel, ASTM Type 304 or 316, PVC, or Teflon®, two-inch minimum inside diameter, threaded, flush-jointed pipe is most commonly used. If the screen is constructed of stainless steel, the screens will be of the continuous slot, wire-wound, welded construction type. If Teflon® or PVC is used, the screen will be of the non-continuous, machine-slotted type. Slot size is matched to formation characteristics, and should be selected to retain from 90-100% of the filler pack material, or from 50-100% of the formation in naturally packed wells (EPA, 1992). For piezometers, PVC, Schedule 40, two-inch minimum inside diameter, threaded flush-jointed, with slot size matched to formation characteristics is most commonly used.[2]

Bottom Caps: For monitoring wells, stainless steel, ASTM Type 304 or 316, or Teflon®, threaded to match the well screen, is used. For piezometers, PVC, threaded to match the screen, is used.

Well Caps: PVC, Teflon®, or stainless steel is used as required. Well caps should be threaded or push-on type to match the diameter and construction material of the casing and vented to maintain the ambient atmospheric pressure within the casing.[3]

Filter Pack: A chemically inert material, such as silica or quartz sand should be used, which is bagged and certified clean by the manufacturer. Filter material is sieved or graded to a specific size that will prevent formation materials from entering the screened interval; EPA (1992) recommends various techniques to determine filter pack size, such as determination of filter pack material size by multiplying the 70% retained grain size of the formation materials by a factor of 4 to 6.

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[2] A piezometer may also serve as a monitoring well, in which case, the well construction materials must be selected to be compatible with the parameter(s) to be monitored and the expected hydrogeologic environment.

[3] If the well is not covered by a protective casing, the well cap should be threaded and equipped with a locking device.

Annular Seal Above Filter Pack: Sodium bentonite pellets[4], certified free of additives by the manufacturer, are typically used.

Grout for Annular Space Above the Seal: A mixture of Portland cement and bentonite, or Portland cement alone, is used. The Portland cement will typically be ASTM Type I or Type II, and the bentonite may be added in the amount of two to five percent of the dry weight of the cement. Variations to this requirement are sometimes acceptable. For example, EPA Region IV specifically requires that grouts be mixed using 6.5 to 7 gallons of water per 94-pound bag of Portland cement (Type I). Furthermore, several commercial high solids (30 percent solids), polymer free, sodium bentonite grout mixtures for monitoring well completion are also available for use. These consist of Pure Gold Grout and Volclay Grout (manufactured by American Colloid) and Enviroplug Grout (manufactured by Wyo-Ben, Inc.).

Centering Guide or Centralizer (if used): A centralizer is used to center longer strings of well casing material within a borehole prior to addition of filter pack or annular seal. The centralizer is typically constructed of the same material as the casing, although stainless steel centralizers may be used in lieu of PVC.

Surface Casing: Carbon steel pipe, ASTM-STD, with threaded or welded joints, or PVC[5], Schedule 40, which is threaded flush-joint or coupled, is normally used.

Protective Casing (if used): Carbon steel pipe, ASTM-STD, with a locking cover[6], or a self-draining, flush-mounted road box with a cover are commonly used.

Portland Cement Concrete for Pad: Use a standard mix for exposed structures utilizing ASTM Type I or Type II cement and a water-cement ratio, by weight, of no more than 0.50 (+/- 0.02).

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4 Coarse grit or powdered bentonite may be specified for certain applications.

5 Steel surface casing is preferred; however, PVC may be used for certain installations up to 100 feet in depth.

6 Required in areas where the well(s) may be threatened by the activity of motorized equipment or other vehicular traffic.

Guards: Concrete or steel bumper guards, or carbon steel posts can be installed around the well to guard against damage. These should be placed within 3 to 4 feet of the well, be of sufficient height to be visible to vehicular traffic, and painted orange or another highly visible color and/or fitted with reflectors to reduce the possibility of vehicular damage (EPA, 1992).

Well Development Equipment

Monitoring wells must be developed to remove fine particles from the well and to create an effective filterpack. Many techniques to develop wells are available, and include but are not limited to:

Pumps or Bailers: The process of pumping or bailing water from the recently installed monitoring well is similar to other well development techniques. The goal is to generate the movement of water through and around the filter pack, the screen and the well casing to remove any water added during installation of the well, and to remove finer particles from the well screen and filter pack. It is imperative to ensure that the groundwater extracted from the well is representative of the aquifer conditions that the well screen is placed in. If pumping or bailing is not effective in developing the well, then it may be necessary to implement one or more of the more aggressive well development techniques mentioned below. The advantages to pumping and bailing is the relatively minimal equipment necessary and the ease of their use.

Surge Blocks: Surge blocks are used to induce flow reversal and aid in the removal by lifting and lowering the block, accompanied by pumping of surged water/fines. Surge blocks are commonly constructed of two rubber or leather disks sandwiched between three steel or wooden disks. The outside diameter (OD) of the rubber disks equals the inside diameter (ID) of the well screen, while the hard disks are one inch smaller in diameter than the screen. The well is developed by raising and lowering the surge block inside the well casing.

Swabbing Tools: Common swabbing tools include the line-swabbing tool or a double-flanged swab. The line-swabbing tool is typically a rubber-flanged bailer or mud scow, which is quickly raised in the screen to produce a pressure differential. The double-flanged swab pumps water between two rubber flanges and returns water to the well borehole above or below the flanges. A bypass tube may be installed in the double-flange swab to facilitate water movement up the borehole from below the tool.

Airlifting/Surging or Jetting[7]: Air compressors are necessary if air-lift development or surge-and-lift development techniques are used to "blow" material from the well. An organic filter must be used in the air line if the well is to be sampled. Pumps of various capacities are used for surging or jetting purge techniques. Pumps may be used to force air or water into the well borehole during jetting operations, or to remove sediment from the borehole after development. Jetting tools are used to force water or air through the well screen. These tools generally have two or more nozzles through which the fluid is forced into the borehole. The jetting tool is normally only slightly smaller in diameter than the screen to allow the jetting fluid to enter the well borehole close to the screen.

Support Equipment and Accessories

Additional materials, items, and equipment are required for the construction, installation, or development of a well, that are not part of the completed well. The more commonly-used items are listed below.

Steam Cleaner: Steam cleaning is required to decontaminate equipment (e.g., drill rig, drill rods, bit, well construction materials), both before and after drilling and between drilling locations. Steam cleaning may also be used for the initial cleaning of some sampling and development equipment. The steam cleaner should be capable of generating a pressure of at least 2500 psi and a water temperature of at least 200° F.

Detergent: Non-ionic, non-phosphatic, laboratory-grade detergent, such as Alconox or Liquinox, is generally used to clean and decontaminate drilling, sampling, and development equipment.

Absorbent Wipes: Wipes are needed for cleaning and decontamination of equipment.

Plastic Sheeting (if used): Plastic sheeting can be used as a ground cover to keep well installation materials off soil or other surfaces.

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[7] EPA (1992) states that development methods which require addition of emplaced water or air to the monitoring well could compromise groundwater sample quality, and are hence unsuitable in most instances. These methods include airlift pumping, air surging, and jetting.

Thread Lubricants: Potable water or other material as specified in the sampling and analysis plan, is sometimes needed to lubricate threads on the casing and well screen. Several new organic-free and polymer free lubricants are presently on the market; however, prior to use, such lubricants must be approved by the client.

IV. Borehole Drilling

The installation and development of a well will usually require the drilling of a borehole. Two different methods of borehole drilling are presented below.

Boreholes Installed in Unconsolidated Materials

Unconsolidated material characteristics will determine the borehole drilling method to be used. The hollow-stem continuous flight auger system is typically used in relatively fine grained materials such as sand, silt, soft clay, and moderately cherty or gravelly deposits; however, large cobbles, boulders, or chert blocks may effectively prohibit auger penetration. Air rotary or air hammer methods, when used in conjunction with the driving of casing, are effective in heterogenous deposits such as boulder laden till or alluvium, coarse gravel and chert, and in hard clay.

Air rotary and air hammer systems typically employ a temporary casing advance method by which a temporary casing that is about the same diameter as the hole, is advanced behind the bit following the drilling of each interval. The monitoring well is built within the temporary casing, as the inside diameter of the temporary casing will be at least four inches larger than the outside diameter of the inner well casing. The temporary casing is then withdrawn as well construction progresses.

Well installations in non-cohesive formations, which will not maintain an open borehole, may require special techniques to prevent holes from closing before the wells are in place. For example, when using hollow-stem augers, the well is constructed inside the auger before the augers are removed.

Formation sampling is accomplished inside hollow-stem augers by means of Shelby tube, split-spoon, or continuous sampling devices. The samples obtained in this manner will be representative of a discrete stratigraphic interval. The air rotary and air hammer systems do not allow for similar collection of discrete samples, as these methods "lift" cuttings with filtered compressed air through the annular space between the drill rods and the temporary casings to ground surface.

Boreholes Installed in Consolidated Materials

Boreholes into bedrock are typically drilled using the air rotary/air hammer method, or the mud rotary method with a rock bit. When the bedrock well site is overlain by an unconsolidated zone, a surface casing is first installed through the unconsolidated zone at least two feet into bedrock to maintain an open borehole and to prevent cross-contamination of the different stratigraphic intervals. The initial borehole for a permanent installation will allow an annular space of at least two inches between the borehole and surface casing through which cement grout can be introduced to seal and stabilize the outer casing. The surface casing should be grouted and allowed to set for a minimum of 24 hours before continuation of drilling. The inside diameter of the surface casing must be at least four inches greater than the outside diameter of the inner well casing. Once the surface casing has been installed, drilling into bedrock can continue.

The use of drilling fluids (i.e., water, muds, polymers, foams) is usually discouraged, but in cases of known or suspected formation or groundwater contamination, drilling fluids may be used as necessary to suppress respirable contaminated dust. Also, water may be needed in certain adverse drilling conditions. The use of such fluids will require prior approval by the client, and all drilling fluids will be analyzed and certified clean by the manufacturer.

V. Well Construction/Installation

Once well borehole(s) have been drilled, well installation can be initiated. Different techniques are used depending on the sub-surface conditions encountered.

Wells Constructed/Installed in Unconsolidated Materials

Primarily, wells are constructed/installed in unconsolidated materials as described from the bottom of the borehole to the ground surface.

Casing and Screen with Bottom Cap: The casing, with screen and bottom cap attached, is lowered either into the borehole or through the hollow-steam auger until the screen reaches the horizon to be monitored. The installed well casing will typically extend two and one-half to three feet above the ground surface. If necessary, Centralizers may be used to ensure that the well casing is positioned in the center of the borehole so that the filter pack can settle around all of the casing. Centralizers should be attached, if necessary, at regular intervals, beginning just above the position of the bentonite annular seal and attached to the screen or to the portion of the casing which is exposed to the filter pack and the bentonite seal. A typical unconsolidated zone well construction is presented in Attachment A.

Filter Pack: The filter pack must be placed around the screen to approximately two feet above the top of the screen.[8] The filter pack must be installed to ensure no bridging or gapping, which is often best accomplished via the tremie pipe method, particularly for deeper wells.

Bentonite Seal: A seal of sodium bentonite must be placed in the annular space immediately above the filter pack. The bentonite seal must be placed to approximately two feet above the top of the filter pack (see Footnote No. 8). If the seal is within the saturated zone, bentonite pellets must be used; otherwise granulated bentonite may be suitable. The bentonite seal should be emplaced to ensure no bridging or gapping, which is often best accomplished via the tremie pipe method for deeper wells (greater than 30 feet deep). The bentonite pellets should be allowed to hydrate and swell before the overlying grout is emplaced.

Annular Space Grout Seal: Grout must be emplaced in the annular space above the bentonite seal. A heat cement or shrinkage-compensated heat cement grout seal should be used, with bentonite added if the grout is installed below the water table. If a tremie pipe is used to emplace the grout, care should be taken to ensure no disruption of the underlying bentonite (e.g., equipped with a deflector). The grout should set (or cure) a minimum of 24 hours before the concrete surface pad is set.

Well Cap: A threaded (or push-on), vented well cap must be installed on the top of the well casing. If protective casing is not used, the well cap must be equipped with a lock.

Protective Casing with Locking Cap: If a protective casing is installed around the top of the

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[8] The position of the top of the filter pack and the bentonite seal can be checked by "tagging" with a weighted tape measure or other suitable means.

well casing, it must be set in Portland cement concrete to a depth of at least two feet below the ground surface, anchored below the frost line. The inside diameter of the protective casing must be at least four inches greater than the outside diameter of the well casing. The protective casing must extend to approximately four inches above the top of the well casing, and be equipped with a lockable cap. Weep holes must be drilled at the bottom of the protective casing to promote draining of precipitation collected between the protective casing and inner well casing. If a self-draining, flush mounted road box is used, a sanitary seal at the wellhead must be maintained to prevent fluids from entering the well.

Concrete Pad and Protective Posts: A pad of reinforced Portland cement concrete, at least two to three feet in diameter and four inches thick, should be constructed around the well. The pad must be formed in-place and poured integrally with the concrete used to set the protective casing. In areas where frost heave is a concern, the concrete pad and protective casing must extend into the ground to below the frost line. Steel protective posts, if required should be installed around the pad. The posts should be set in concrete three to four feet from the well casing, and extend at least three feet above the ground surface.

Wells Constructed/Installed in Consolidated Material (Bedrock Wells)

The construction and installation procedures for bedrock wells are generally the same as those for wells in unconsolidated material, except as described in the following cases.

Surface Casing: As discussed previously, an outer surface casing may be installed through unconsolidated materials and should be set at least two feet into bedrock. Grout should be emplaced in the annular space between the casing and the borehole wall, and the casing must be installed plumb in the borehole so that a drill string can be run through the surface casing for continued borehole installation into bedrock. The grout must be allowed to harden for at least 24 hours before continuation of the well installation.

When the surface casing installation is complete (i.e., the casing is plumb and the grout hardened), the borehole will be extended into bedrock to the prescribed depth. The well may then be completed according to the procedures for wells in the unconsolidated zone.

Open-Interval Bedrock Wells: A well installed in competent bedrock which is generally free of deletrius, or loose material that would clog the boring, sometimes may be completed with the sampling interval open (i.e., without a well screen). After the surface casing has been set, the borehole must be extended into bedrock to the specified depth for the bottom of the casing. The casing, without a screen or bottom cap, must then be installed to that depth. A float shoe may be attached to the casing, as well as centralizers, and the annulus must be pressure-grouted through the casing from the bottom up. When the grout has hardened, the plug (and the float shoe) is drilled through, and the borehole extended to its full depth. Monitoring well completion in this fashion must be approved by the client and must be installed to ensure well integrity is maintained (e.g., no grout in contact with sampled groundwater). In each portion of the borehole (i.e., surface casing, well casing, and open interval), the diameter of the borehole is reduced to accommodate the drill bit inside the existing casing.

Piezometers

Piezometers should be constructed and installed in a manner similar to other wells. Features which are not typically required for piezometers are surface casing (in bedrock installations), protective casing, and concrete pads. However, site-specific conditions may require any or all of these.

Disposition of Well Cuttings and Wastewater

Wastes generated during environmental surveillance activities located in and around RCRA-regulated units and remedial investigation sites have the potential for being contaminated with hazardous waste, hazardous constituents, and radionuclides.

If it cannot be clearly demonstrated that contamination does not exist, well cuttings and wastewater must be regarded as potentially contaminated and must be collected, containerized, and stored pending characterization. The proper disposition of site-generated waste must be determined on a site-specific basis.

Well Development

Well development is used to restore the hydraulic conductivity which existed in an aquifer prior to drilling the well borehole, and to remove any loose or entrapped sediment in the formation near the well screen. Each well must be developed as soon as practicable, but not before 24 hours has elapsed from the time the installation is completed. The development may include pumping and/or surging (see description of well development equipment). Surging is a technique in which water is forced into and out of a well screen by operating a plunger-like device up and down inside the well casing. The surging may be accomplished by means of a surge block, a heavy bailer, or a swabbing tool as appropriate. Surging must occur over the entire screened interval to be effective.

Air must not be directly injected into the formation as this technique could shatter the PVC casing and "air-lock" the formation. Formation water should be used for developing a well, but some low-yield formations may require additional potable water to complete the development. Initially, at least three to five times the standing water volume in the well should be removed. Any water used and lost in drilling should also be removed in an amount equal to five times the volume used or lost. The well must be developed until the groundwater exhibits low turbidity, of less than 5 NTUs (EPA, 1992). Stabilization of water temperature, specific conductance, and pH can also be used as indicators of adequate well development.

Equipment Cleaning/Decontamination

The drilling equipment, all downhole sampling equipment, and all tools and accessories used at the drilling site must be cleaned before drilling commences, and decontaminated between holes and after cessation of a drilling project.

The cleaning and decontamination must be accomplished according to the SOP on decontamination (SOP No. 02-04-XX)[9]. Spent cleaning and decontamination solutions must be handled in a manner similar to that required for well cuttings and wastewater.

VI. Documentation and Records

A permanent record must be maintained for each monitoring well installation in a field logbook.

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[9] For example, in EPA Region IV the Environmental Services Division Standard Operating Procedures (ECBSOPQAM) requires that all drilling and sampling equipment be subjected to a six-step decontamination procedure. Other Regions may require similar decontamination procedures.

This record should include, but may not be limited to, the following items.

- Well identification number
- Date/time of construction
- Name of drilling company and geologist logging the well
- Drilling method
- Well location (+/-0.1 ft.)
- Borehole diameter and well casing diameter
- Drilled well depth (+/-0.1 ft.)
- Static water level
- Presence/thickness of immiscible layers and detection method
- Drilling and lithologic logs
- Description of casing materials
- Description of screen materials and design
- Casing and screen joint type
- Screen slot size/length
- Filter pack material/size, grain analysis
- Filter pack volume calculations
- Filter pack placement method
- Description of sealant materials (percent bentonite)
- Sealant volume (lbs/gallon of cement)
- Sealant placement method
- Surface seal design/construction
- Well development procedure, including purge volume, rate, and time
- Type of protective well cap
- Ground surface elevation (+/-0.01 ft.)
- Surveyor's pin elevation (+/-0.01 ft.) on concrete apron (if applicable)
- Top of monitoring well casing elevation (0.01 ft.)
- Top of protective steel casing elevation (0.01 ft.)
- Well yield
- Detailed drawing of well (include all dimensions and associated lithological information)

VII. Health and Safety

It is TechLaw's policy to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress which is consistent with OSHA and other applicable and appropriate established standards and requirements.

All field personnel will be provided with appropriate protective clothing and safety equipment. At a minimum, this will include steel-toed shoes, safety glasses, and chemical-resistant gloves.

A site-specific health and safety checklist/plan must be developed by the Field Team Leader or designee and approved by the TechLaw Health and Safety Director prior to implementation in the field. This checklist/plan must be reviewed prior to beginning work.

Any deviation(s) from an approved site-specific health and safety checklist/plan must be documented in the field logbook.

VIII. QA/QC

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site-specific procedures. The site Quality Assurance Project Plan should be consulted to determine additional quality control requirements.

IX. Comments/Notes

None at this time.

X. Attachments

Attachment A - Typical Well Construction Diagram

XI. References

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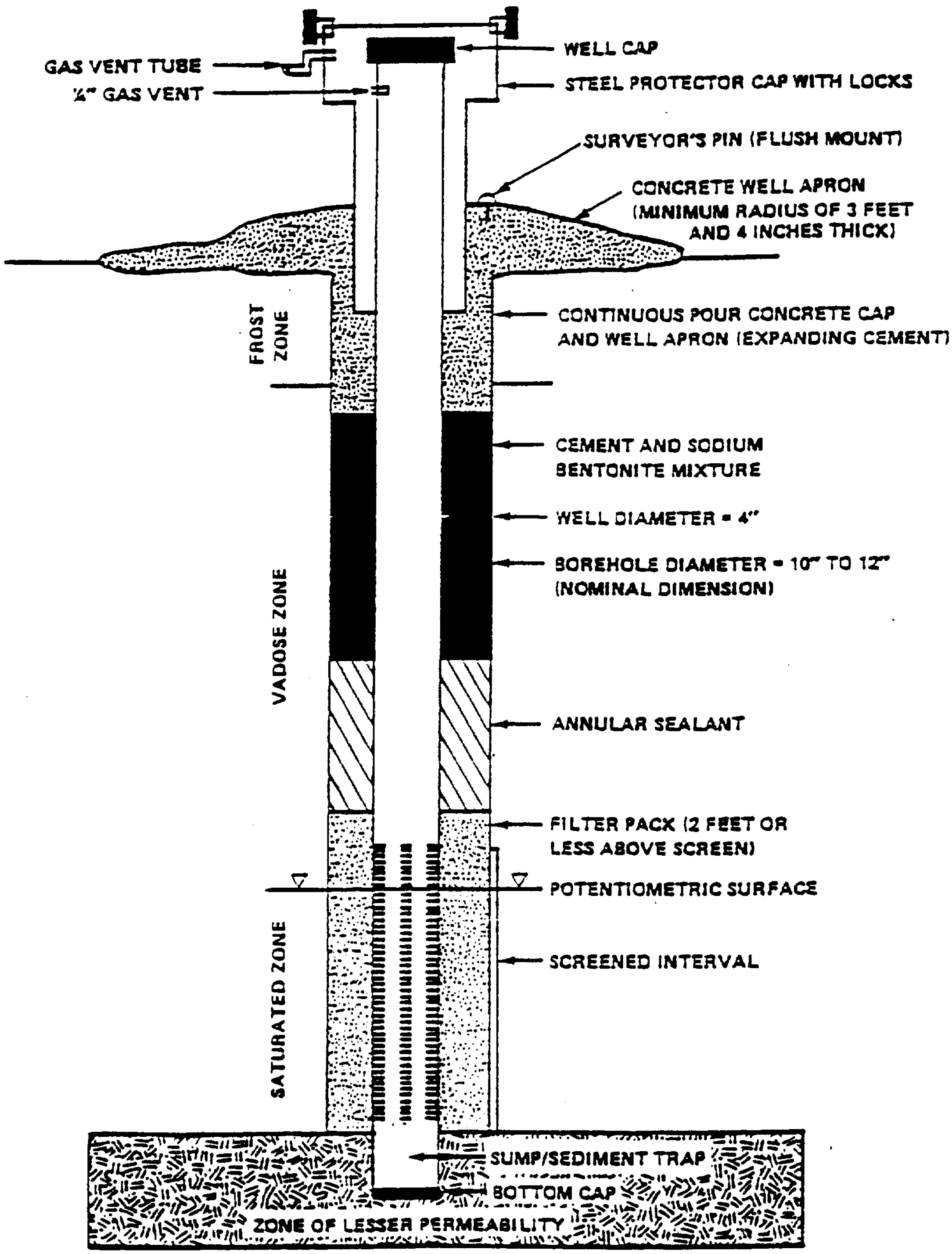
ATTACHMENT A
SOP NO. 06-02-00

Well Design in Unconsolidated Material



Source: U.S. EPA Groundwater Monitoring Technical Enforcement Guidance Document, 1986

RETURN

GROUNDWATER SAMPLING/MONITORING AND ANALYSIS PROCEDURES - PRE-SAMPLING ACTIVITIES

SOP Number: 06-03-01
Effective Date: 03/05/99

Technical Approval: ______________________ Date: 4/29/99

QA Management Approval: ______________________ Date: 6/21/99

SOP Description

This Standard Operating Procedure (SOP) presents the procedures to be followed by TechLaw staff when conducting pre-sampling activities prior to groundwater sampling. The SOP is applicable for work assignments/engagements conducted for either government or commercial clients. Pre-sampling activities include preparation of the well prior to sampling, water-level measurement, well purging, and other related groundwater measurement activities. Additional groundwater sampling and analysis related procedures (i.e., development of the sampling and analysis plan [SAP], well installation and development, sampling activities, and well abandonment) can be found in SOP Nos. 06-01-XX through 06-05-XX.

General Procedures

Related SOPs

This SOP is to be used in conjunction with other relevant or applicable SOPs found in the following SOP categories:

Section No.	Section Title
01	General Procedures
02	Field Procedures
03	Field Documentation Procedures
04	Packaging and Shipping Procedures
05	Field Equipment Operation and Maintenance Procedures
06	Groundwater Sampling/Monitoring and Analysis Procedures
10	Regulatory Compliance Procedures
11	Quality Assurance Procedures

Related Documentation

The following documentation is to be collected and available on site when conducting pre-sampling activities:

- Health and safety plan (HASP);

- Sampling and analysis plan (SAP);

- Quality Assurance Project Plan (QAPjP), if available;

- Well log(s) depicting well construction information including, if available:

    - Location of well(s),
    - Diameter of well(s),
    - Depth of well(s),
    - Screen interval(s),
    - Filter pack interval(s), and
    - Other relevant well construction information;

- Other relevant available facility/site information; and

- Field logbook(s).

Equipment and Apparatus

Equipment used for monitoring well sampling and purging activities must be properly calibrated and tested prior to use. All equipment (e.g., organic vapor analyzer [OVA], HNu meter, explosimeter, O_2 analyzer) must be calibrated in accordance with the manufacturers' specifications in a clean area on site (e.g., support zone or off site). Any instrumentation not meeting the manufacturers' performance criteria should be returned for repairs. In addition, instrument calibration schedules, as well as any deviations in performance criteria, must be recorded in the field logbook.

Equipment that may be needed to support the pre-sampling activities include the following:

- Wrench for opening the well cap;
- Well lock keys and/or lock combinations;
- Plastic drop cloth;
- Folding engineer's ruler or other measuring device;
- Water level measuring device (e.g., electric water level indicator, interface probe);
- Thermometer or temperature measuring device calibrated in degrees centigrade with an accuracy of $\pm 1°$ (or to the accuracy specified in the SAP);
- Dissolved oxygen meter with an accuracy of ± 0.1 mg/ℓ, if needed;
- pH meter with an accuracy of ± 0.1 pH units;
- Conductivity meter, preferably with the capacity to report conductivity (micromhos/cm) corrected to 25°C;
- Organic vapor detection devices (e.g., OVA, HNu, PhotoVac TIP) and explosimeters, as necessary;
- Container(s) for field measurement of pH, conductivity, temperature, etc;
- Purging equipment - bailer or pump, as required by the SAP;
- Power source for pump (i.e., electrical generator, air compressor, or electrical outlet), if appropriate;
- Container of known volume (5-gallon minimum) for measuring purge water or flow rate;
- Stopwatch or other time measuring device;

- Appropriate personnel protective equipment including disposable, chemically inert gloves (separate pair for each well location) as required by the approved HASP;
- Decontamination and cleaning agents (e.g., laboratory detergent, deionized water, paper towels);
- Packing materials;
- Container(s) for storing purge water (if required by facility and/or SAP); and
- Any other site-specific equipment specified in the SAP.

<u>General Considerations</u>

Whenever non-dedicated equipment is used, decontamination procedures must be instituted to ensure that the equipment, well, and samples are not cross-contaminated from outside sources. All equipment required for water-level measurement must be constructed of inert materials and must be assembled, calibrated, and tested prior to arriving at the site. Any item which potentially comes in contact with the sample water must be disposed of or thoroughly cleaned prior to use at a new well location. In addition, all equipment should be kept out of direct sunlight to avoid temperature fluctuations, if sensitive to these changes. Plastic sheeting should be placed around the base of the well casing to prevent contamination of the sampling equipment if accidentally dropped or intentionally placed on the ground surface.

Monitoring wells should be properly prepared prior to water level measurement and sample collection. Well preparation activities include clearing all trash, debris, and vegetation from around the well casing, measurement of the ambient environmental safety conditions around the well (e.g., detection of hazardous vapors or explosive environments), and a general inspection of the well integrity. All observations and measurements should be recorded in the field logbook, and photographs should be taken of any abnormalities (e.g., bent well casing, cracked concrete well pad) that could adversely affect the integrity of the well and the resulting groundwater sample.

The device used to detect the water level surface must be of sufficient sensitivity to measure the water level to within ± 0.01 foot. An electric water level indicator will be used to measure the depth to the groundwater surface. In wells where light and dense-phase immiscible products are present, or suspected to be present, an interface probe should be used. Water-level indicators are portable instruments that generally do not require outside power sources to operate. However, some require batteries that need to be replaced or recharged periodically. The SAP specifies the device(s) to be used for conducting water-level measurements. Specific water level measuring devices are discussed below.

- **Electric Water Level Indicator** - An electric water level indicator consists of a brass, stainless steel, or other metal conductive probe attached to a conductor wire which is covered by a coated PVC, HDPE, Teflon®, Tefzel® (or other materials) engineer's tape. The tape is marked off in intervals, typically five feet or less, to allow for the determination of the depth to water. The indicator is lowered into the borehole, and either a light comes on or an alarm is sounded when water is contacted by the conductive probe. The spacing of the markings on the indicator tape should be checked periodically with surveyor's tape to assure accurate and reliable readings. There are a number of commercial electric water level indicators available.

- **Interface Probe** - An interface probe is similar to an electric water level indicator except that the probe is capable of detecting organic liquids, principally non-aqueous phase liquids (NAPLs), in the well. NAPLs can be differentiated into light non-aqueous phase liquids (LNAPLs) and dense non-aqueous phase liquids (DNAPLs). LNAPLs generally tend to float on the water table surface, while DNAPLs sink to lower levels in the aquifer. The probe is used to measure the depth to the air/LNAPL interface, and then the depth to the LNAPL/groundwater interface. By this process, the thickness of the LNAPL layer can be determined. Interface probes are also available for measuring the thickness of DNAPL layers in the bottom of wells.

Water-level measurements are conducted in conjunction with, and prior to, well purging. Specific measurements to be recorded include depth to standing water, total depth of the well measured to the bottom of the riser/screen assembly, and well casing diameter. Additional information which should be gathered from the well completion logs include the drilled total depth of the well (including the lengths of any well sumps) and the height of the filter pack. This information is required to calculate the volume of stagnant water in the well and can provide a check on the integrity of the well (e.g., identify siltation problems). The measurements should be recorded to an accuracy of 0.01 foot. Each well should have a permanent, easily identified reference point on the well casing established by a licensed surveyor from which the water-level elevation is measured. The reference point usually consists of either a notch cut in the top of the riser pipe, or a mark or plate permanently attached to the well casing.

Stagnant water within a well is purged prior to sampling to ensure that the groundwater sample collected for analysis is representative of the groundwater within the aquifer. The device selected for purging (e.g., bailer or pump) depends upon the aquifer properties, individual well construction details, available equipment, and data quality objectives.

When sampling several wells at a facility, the samples should be collected from the least contaminated wells to successively more contaminated wells (or from upgradient to downgradient).

Well Preparation and Water-Level Measurement Procedures

Monitoring well measurements may be made with a number of different instruments. Specific instrumentation required for each site should be outlined in the SAP. Measurements are collected from a scribed point placed by a surveyor, as stated above[1]. Well preparation and water-level measurement activities, which should be completed prior to sampling, include the following:

- Calibrate all field instruments according to the manufacturers' instrument calibration and maintenance manual in a clean area on site (e.g., the decontamination area).

- Locate the well and record the well number, site, date, and well condition in the field logbook. Document any conditions which could compromise the integrity of the groundwater sample (e.g., cracked concrete pad, bent protective casing, broken padlock, paint or oils on the inside of the riser pipe);

- Lay out necessary equipment on a plastic drop-cloth adjacent to the well so that the equipment does not directly contact the underlying ground surface;

- Remove the tamper-proof locking well cap (if applicable);

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1 The point at which the elevation was measured on the well (e.g., top of the inner well casing, top of the outer protective casing, top of the concrete pad) should be scribed on the well to ensure that water level elevations can be measured from the same location for each event.

- Measure the organic vapor concentrations inside the well casing following the procedures outlined in SOP Nos. 05-03-XX and/or 05-07-XX. If potentially explosive conditions are anticipated, measure the lower and upper explosive limits with an explosimeter, as described in SOP No. 05-02-XX;

- Measure and record the depth to water and the time of measurement in the field logbook;

- Remeasure and record the depth to water after a lapse of four to eight minutes following the initial measurement. Record the depth to water and time of measurement in the field logbook;

- If successive measurements show essentially no difference (i.e., less than 1/100th ft.), continue with the next step. Where the level change is greater than 1/100 ft., continue measuring until the change observed and recorded is less than 1/100 ft.;

- If the well is completed in consolidated bedrock, use the total well depth measured when the well was installed for the actual well depth in any calculations;

- If the well is completed in unconsolidated sediments, record the measurable total depth of the well. The measurable total depth of wells completed in unconsolidated formations may not equal the drilled total depth due to the infiltration of silt or sand into the bottom of the well. Usually, the silt or sand is collected in a well sump, attached to the bottom of the screen. If well completion logs are available, determine the total depth of the well (casing and screen) as originally installed. Compare the original total well depth to the measurable total depth. Any deviations from the original total depth could be due to: silt/sand infiltration in the bottom of the well; bent well casing; or silt/sand bridging across the casing. Record any observed deviations in the field logbook;

- In deep wells with long water columns, it may be difficult to determine when the tape end is touching the bottom of the well due to tape buoyancy and weight effects. Measure the total depth of the well (Z_{WB}) to the nearest 0.1 foot according to the following steps and enter the time of measurement in the field logbook:

  - Lower the tape or cable through the water column until the weighted end is on the bottom of the well (this is most easily noted when tension on the tape is removed),
  - Pull the tape off the bottom and slowly lower the tape until tension is first released, and

- Record the well depth (total length of tape from the bottom of the well to the point at the surveyor's mark) using the marks on the tape for measurement in the field logbook;

- Calculate the height of the standing water column (h_{WC}) in the well using the following formula and record in the field logbook;

$$h_{WC} = Z_{WB} - Z_{SWL}$$

where
h_{WC} = height of standing water column
Z_{WB} = total measurable depth of wellbore
Z_{SWL} = depth to static water level

- Calculate the volume of water standing in the well. This is determined by using the following formula:

$$V = 0.041\ d^2 h_{WC}$$

where
V = volume of water in the well (in gallons)
d = diameter of well (in inches)
h_{WC} = height of the water column (in feet)

Record the volume in the field logbook;

- If the well construction logs indicate the diameter of the drilled borehole prior to well completion (i.e., prior to the installation of the screen and riser), the approximate volume of water in the filter pack can also be calculated using the formula described above. Water in the filter pack is usually stagnant and should be removed during well purging procedures.

  The formula for calculating water in the filter pack is the same as above with the exception of: the well diameter (d), which now equals the diameter of the drilled borehole prior to well completion (which is greater than the diameter of the well casing) minus the diameter of the casing; the water column height (h_{WC}), which now equals the height of the saturated filter pack only; and the addition of a void volume factor, which is equivalent to the porosity of the filter pack. To determine the volume of water present in the filter pack only, the above formula is applied, with the results multiplied by the porosity to acquire the actual water volume in the filter pack only. However, the porosity of the filter pack is difficult to determine accurately, and many workers estimate the volume of water in the filter pack by assuming that this volume is equal to the total well volume (calculated using the borehole diameter) minus the volume of water in the casing. This latter method provides a very conservative estimate of the water in the filter pack.

Separate calculations of the water volume within the well and the volume within the filter pack may be recorded in the field logbook; however, it is also acceptable to record only the <u>total</u> water volume (water in both the filter pack and well), provided that the log book clearly indicates which volumes have been calculated and how those values were determined. Example calculations of the total water volume, volume in the well, and volume in the filter pack are shown in Attachment A;

- Ensure the following data has been entered into the field logbook:

  - well depth (Z_{WB})
  - well bore diameter (d_{WB})
  - well casing diameter (d_C)
  - height of filter pack (h_{FP})

  The well is ready to be purged once the well bore water volumes have been calculated.

Well Purging Procedures

Wells may be purged with either a bailer or pump. The procedures required for each method are discussed below. Wells should not be purged by the airlift method, as this approach may cause the formation to "airlock", which reduces the ability of the well to yield water.

Bailer Purging Procedures

- Decontaminate non-dedicated equipment prior to use in the well bore in accordance with the procedures outlined in SOP No. 02-03-XX.

- Tie a new rope or wire cable to a "clean" (i.e., dedicated or properly decontaminated) bailer. Nylon rope may be used provided it is replaced between sampling stations. If reusable wire cable is to be used to lower the bailer down the well, a Teflon® coated wire leader should be used between the cable and bailer.

- Begin bailing the well, placing purged water into appropriate drums, polyethylene tanks, or other containers near the well, if required.

- Measure initial field parameters (e.g., pH, temperature, specific conductance) until stabilization has been obtained (see below), and record these data in the field logbook.

- Regulate the rate of purging to minimize agitation of the groundwater. When using a bailer to purge the well, lower and raise it slowly so as not to agitate the water in the well. Water will be removed from the top of the water column using this technique.

- Calculate the volumes of water removed from the well. This may be accomplished by keeping track of the total number of bailer volumes removed, or by pouring the water from the bailer into a container of known volume (e.g., graduated 5-gallon bucket) and keeping track of the total volume in the container. Document all volumes removed from the well in the field logbook.

- The well will be purged when a total of three to five well volumes [V_W] (or more, as specified in the SAP) have been removed. The SAP should designate whether the purged well volume is to include the volume contained in the filter pack, as discussed in the previous section. Purging is complete when field parameters have stabilized over three to five consecutive well volumes. Purging is also complete if the well is bailed to dryness.

  Field parameters are considered to be stabilized when pH measurements agree within 0.1 units, temperature measurements agree within 1°C, and conductivity measurements are within 10 percent. (Refer to the appropriate SOP for each instrument.) If readings do not stabilize after five well volumes (or the number specified in the SAP), obtain additional guidance from the client. However, it should be noted that U.S. EPA usually considers the well to be adequately purged once five well volumes have been removed.

- Continue purging until complete.

- Record all purge times, rates of well evacuation, and total volume purged in field logbook.

Pump Purging Procedures

- Connect a discharge pipe to the outlet of the pump, and lower the pump to intake the appropriate depth within the well. Ensure that the pump intake is positioned near the upper surface of the standing water column, and not deep into the column. This ensures that the pump will pull water from the formation into the screened area of the well and up through the casing so that the entire static volume can be removed. If the pump intake is placed too deep in the water column, the water above the pump may not be removed.

- Connect the pump to the appropriate power source and turn on the pump to begin purging. Dispose of the water in appropriate containers near the well, if required.

- Measure the initial values of the field parameters (pH, temperature, specific conductance) and record in the field logbook.

- Measure the initial pump discharge rate by measuring the time required to fill a container of known volume.

- Calculate the total purge time, using the initial discharge rate. Measure pump discharge rate every five to ten minutes to determine discharge variation. Alternatively, purge the well into a container of known volume (e.g., 5-gallon bucket) in order to track the amount of water purged.

- The well will be purged when a total of three to five well volumes (or more as specified in the SAP) have been removed. The SAP should designate whether purged well volumes should include the volume contained in the filter pack, as discussed in the previous section. Purging is complete when field parameters (pH, temperature, specific conductivity) have stabilized over two consecutive well volumes or over three consecutive readings. Purging is also complete if the well is pumped to dryness.

- Field parameters are considered stabilized when pH measurements agree within 0.1 units, temperature measurements agree within 1°C, and conductivity measurements are within 10 percent. (Refer to appropriate SOP for each instrument.) If readings do not stabilize after five well volumes (or the number specified in the SAP), obtain additional guidance from the client. However, it should be noted that U.S. EPA usually considers the well to be adequately purged once five well volumes have been removed.

- Containerize all purge water and dispose of according to the procedures in the Post-Purging Procedures section.

- Record all purge times, rates of well evacuation, and total volume purged in field logbook.

Post-Purging Procedures

- Prepare to sample the well according to the site-specific SAP.

- When all necessary procedures are complete, lock the well (if appropriate), clean the area, and dispose of refuse in accordance with guidelines set forth in SOP No. 02-04-XX, Management of Investigation-Derived Waste, and the site-specific SOP.

- Dispose of containerized purge water. Refer to the site-specific SAP and SOP No. 02-04-XX, Management of Investigation-Derived Waste.

Documentation and Records

A permanent record must be maintained of pre-sampling activities within the field logbook. Field documentation of pre-sampling activities is also required for field oversight tasks. The logbook should include the following items (where available):

- Identification and condition of the well (site name, well number and location, and general condition of the well), including photographs of well abnormalities;

- Weather conditions and field observations;

- All equipment calibration and maintenance performed in the field, including improper cleaning of nondedicated sampling equipment and deviations in performance criteria;

- Identification of any equipment placed on the ground where it could become contaminated prior to use;

- Any measurement(s) detected with field equipment (e.g., HNu);
- Personnel present at the site;
- Type of well to be sampled (e.g., potable water wells, monitoring wells, piezometers);
- Whether wells were locked and protected;
- Presence of well identification marks and measurement points (i.e., surveyors' marks);
- Well total depth and diameter, and time of measurement;
- Deviations from original well depth due to, for example, siltation;
- Well screen depths;
- Wellbore diameter;
- Well construction materials (e.g., PVC, stainless steel);
- Well casing diameter;
- Height of filter pack;
- Static water level depth and measurement technique, including equipment test/calibration results;
- All associated calculations (e.g., purge volume, volume of water standing in well, total water volume);
- Water-bearing formations and thicknesses (if known);
- Equipment used for purging (include equipment manufacturers and model numbers, if available, as well as calibration and testing results);
- Whether purging equipment was dedicated to the well;

- Purge method (e.g., bailer, pump), purge times, and rates of evacuation;

- Method of determining purge volume (e.g., direct measurement - flowmeter, known bailer volume, graduated bucket and stopwatch; or calculation of wellbore volume);

- Disposition of purge water; and

- Measurement of purge/sample water pH, temperature, and conductivity.

Contamination Control

Sampling tools, instruments, and equipment are to be protected from sources of contamination prior to use and decontaminated after use, as specified in SOP No. 06-04-XX. Also, liquids and materials from decontamination operations are to be handled in accordance with the decontamination SOP No. 02-03-XX. Decontamination water is usually managed in the same manner as purge water.

Health and Safety Section

It is TechLaw's policy to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress which is consistent with OSHA and other applicable and appropriate established standards and requirements.

All field personnel will be provided with appropriate protective clothing and safety equipment. At a minimum, this will include steel-toed shoes, safety glasses, hard hat, and chemical-resistant gloves.

A site-specific health and safety checklist/plan must be developed by the Field Team Leader or designee and approved by the TechLaw Health and Safety Director prior to implementation in the field. This checklist/plan must be reviewed prior to beginning work.

Any deviation(s) from an approved site-specific health and safety checklist/plan must be documented in the field logbook.

QA/QC Section

None at this time.

Comments/Notes

None at this time.

Attachments

Attachment A: Example calculations of well/filter pack water volumes.

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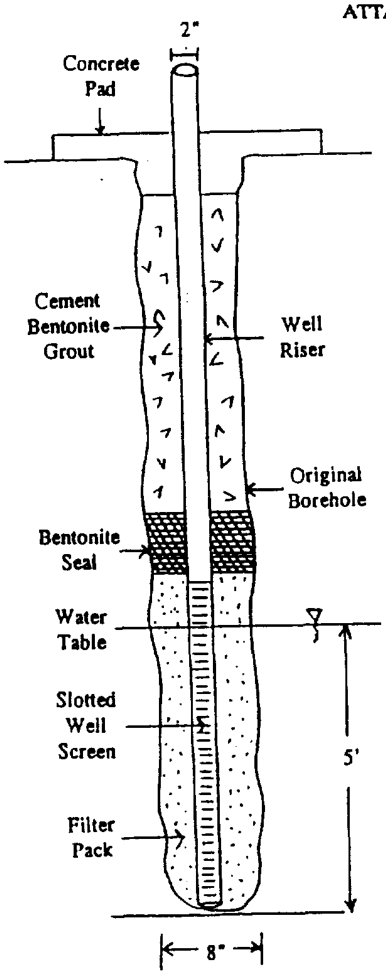

ATTACHMENT A: Example Calculations of Well/Filter Pack Water Volumes

1. Calculation of the <u>total water volume</u> (includes filter pack and well screen/riser):

   $V = 0.041\ d^2h_{wc}$

   where V = volume of water in the well and filter pack (in gallons)
   d = diameter of borehole (8 inches)
   h_{wc} = height of saturated filter pack (5 feet)*

   $V = 0.041\ (64)(5)$
   $V = 13.12$ gallons

2. Calculation of the water volume in the <u>well only</u> (screen/riser):

   $V = 0.041\ d^2h_{wc}$

   where V = volume of water in the well only (in gallons)
   d = diameter of well (2 inches)
   h_{wc} = height of the well water column (5 feet)

   $V = 0.041\ (4)(5)$
   $V = 0.82$ gallons

3. Calculation of the water volume in the <u>filter pack only</u>:

   $V_{FP} = V_T - V_W$

   where V_{FP} = volume of water in the filter pack only
   V_T = total water volume (well and filter pack)
   V_W = volume of water in the well (screen/riser)

   $V = 13.12 - 0.82$ gallons
   $V = 12.3$ gallons**

* For a well with the water level above the well screen/filter pack, use the entire filter pack length.
** No correction for filter pack porosity; actual volume is lower.

Technical Approval: ______ Date: 4/29/99

QA Management Approval ______ Date: 5/11/99

SOP Description

This Standard Operating Procedure (SOP) establishes the procedures and requirements to be followed during groundwater sampling activities. Sampling activities include determining necessary supplies, equipment preparation, sample collection, sample preservation and sample management (i.e., labeling, Chain-of -Custody generation, etc.) sample handling. However, Pre-sampling activities (including preparation of the well, water-level measurement, well purging, and other ground-water measurement activities) are discussed in SOP No. 06-03-XX.

General Procedures

Related SOPs

This SOP is to be used in conjunction with the other relevant or applicable SOPs found in the following SOP categories.

Section No.	Section Title
01	General Procedures
02	General Field Procedures
03	Field Documentation Procedures
04	Packaging and Shipping Procedures
05	Field Equipment Operation and Maintenance Procedures
06	Groundwater Sampling/Monitoring and Analysis Procedures
09	Health and Safety Procedures
10	Regulatory Compliance Procedures
11	Quality Assurance Procedures

Related Documentation

The following documentation is to be collected and available onsite when conducting pre-sampling activities:

- Health and safety plan (HASP);
- Personnel health and safety information (e.g., copies of 40-hour OSHA training, 8-hour supervisors training, and 8-hour refresher training certificates; 24-hour on-the-job training letter; current medical approval; and respirator fit test approval);
- Sampling and analysis plan (SAP);
- Quality Assurance Project Plan (QAPP);
- Field logbook(s); and if available
- Well log(s) depicting well construction information including:
  - Location of well(s),
  - Diameter of well(s),
  - Depth of well(s),
  - Screen interval(s),
  - Filter pack interval(s), and
  - Other relevant well construction/facility information;

Equipment and Apparatus

This section describes the different equipment and methods used in collecting groundwater samples.

Sampling Equipment

Bailers

A bailer is a rigid tube attached to a rope or steel cable that fills with water when lowered into the well. When raised back out of the well, it is sealed on one or both ends, typically by a ball and seat mechanism. Bailers that seal only at the bottom are called single check valve bailers, while bailers that seal at both ends are called double check valve bailers. The advantages of bailers are that they are relatively inexpensive, easy to clean or disposable, portable, simple to operate, require no external power source, and can be constructed of a wide variety of materials that are compatible with the parameter(s) of interest.

Disadvantages of bailers, depending on the well construction (e.g., depth), is that their use can be time consuming and labor intensive and the transfer of water to a sample container may alter the chemistry of groundwater samples due to degassing, volatilization, or aeration (oxidation). In addition, it is difficult to determine the exact location in the water column from which a bailed sample has been collected, and cross-contamination can be a problem if the bailers are not adequately decontaminated between each use. When sampling NAPLs, bailers should never be dropped into a well and should be removed from the well in a manner that causes as little agitation of the sample as possible. When transferring the sample from a bailer to a container, it is preferable to use a bottom emptying device with a valve that allows the LNAPL or DNAPL to slowly drain from the bailer.

Pumps

Pumps historically used for groundwater sampling include bladder pumps, helical rotor electric submersible pumps, gas-driven piston pumps, gear drive electric submersible pumps, centrifugal pumps and peristaltic pumps. A brief description of each of these pumps along with their applications and limitations with regard to groundwater sampling follows.

- Bladder Pumps: Bladder pumps are submersible pumps consisting of a flexible membrane (bladder) enclosed in a rigid (usually stainless steel) housing. The internal bladder can be compressed and expanded under the influence of gas (air or nitrogen). Water enters the bladder through the lower check valve and compressed gas is injected into the cavity between the housing and bladder. The sample is transported through the upper check valve and into the discharge line through compression of the bladder. The upper check valve prevents water from re-entering the bladder. The advantages of bladder pumps include: a wide range of pumping rates; a variety of materials can be used (depending upon the analytical parameters of interest); the driving gas does not contact the water sample, eliminating possible contamination or gas stripping; pump sizes as small as one-inch diameter; and the highly portable nature of the pump. Disadvantages include a high cost for large commercial units and potential bladder rupture. Furthermore, the large gas volumes and long cycles required for deep operations cannot match the rates of submersible or suction pumps. However, bladder pumps are generally recognized as the best overall sampling device for both inorganic and organic constituents.

- Helical Rotor Electric Submersible Pumps: The helical rotor electric pump is a submersible pump consisting of a sealed electric motor that powers a helical rotor. The groundwater sample is forced up a discharge line by an electrically driven rotor-stator assembly by centrifugal action. Pumping rates vary depending upon the depth of the pump. Considerable agitation of water in the well may result from operating the pump at high rates, and this may cause alteration of the sample chemistry. In addition, high pumping rates can introduce formation sediments into the well that are immobile under ambient groundwater flow conditions, resulting in the collection of unrepresentative samples.

- Gas-Drive Piston Pumps: Gas-drive piston pumps use compressed air to force a piston to raise the groundwater sample to the surface. The pump is connected to a tubing bundle which contains three tubes, an electric cord, and a stainless steel cable. The tubes convey the gases to and from the pump; the electric cable powers the water level indicator, and a steel cable supports the downhole assembly. Flow rates can be controlled by adjusting the driving pressure to the pump. The piston pump provides continuous sample withdrawal at depths greater than most other devices. Gas-drive piston pumps perform similarly to bladder pumps when collecting samples for volatile organics analysis. The advantages of gas-driven piston pumps are that they isolate the sample from the operating gas and require no electrical power source and operate continuously and reliably over extended periods of time and can be operated at depths in excess of 500 meters. The disadvantages of the pump include the possibility of damage from particulate material unless the suction line is filtered, and potential pressure drops in the sample which could cause sample degassing and pH changes. Furthermore, the bulk of the associated equipment reduces the portability of the pump, and the tubing bundles may be difficult to decontaminate between wells.

- Gear-Drive Electric Submersible Pumps: Gear-drive submersible pumps are designed to be portable and easily serviceable in the field. A gear-drive pump operates using a small high-efficiency electric motor that is located within the pump housing. The electric motor rotates a set of gears from an intake screen at the top of the pump. The water is drawn through the gears and driven to a discharge line that transports the water to the surface. The pumps have self-contained power sources, however, external sources may be used. Flow rates cannot be controlled on conventional gear-drive submersible pumps. Wells that have high levels of suspended solids may cause the gears to require frequent replacement.

- Centrifugal Pumps: Centrifugal pumps transport fluid by accelerating it radially outward. Specifically, a motor shaft rotates an impeller that is contained within a casing. Water that is directed into the center of the rotating impeller is picked up by the impeller vanes, accelerated by the rotation of the impeller, and discharged by centrifugal force into the casing. Certain submersible centrifugal pumps are constructed for groundwater sampling. Studies have determined that low flow-rate submersible centrifugal pumps may produce less negative impacts than a bladder or peristaltic pumps. These pumps perform similarly to bladder pumps when collecting samples for volatile organics analysis.

- Peristaltic Pumps: Peristaltic pumps are low-volume pumps which operate by suction lift. Plastic tubing is inserted around the pump rotor. Rotating rollers compress the tubing as the rollers revolve around the rotor, forcing fluid movement ahead and inducing suction behind each roller. As the rotor revolves, water is drawn into a sampling tube that has been inserted into the well, and discharged into the sample container. Peristaltic pumps often require the use of flexible silicone tubing, which is unsuitable for ground-water sampling purposes. The withdrawal rate of peristaltic pumps can be carefully regulated by adjusting the rotor head revolution. The use of a peristaltic pump is limited by the depth of sampling; the depth of sample collection is limited to situations where the potentiometric level is less that 25 feet below land surface. Furthermore, an electrical power source is required.

HydroPunch® Sampler

The HydroPunch® is a sampling tool that allows the rapid collection of ground-water samples without installing a monitoring well. Conventional drill rods are used to push the tool to the desired sampling depth. To activate the tool, the drill rods are pulled up 12 to 18 inches, which exposes the sampling port to the water-bearing zone. The probe fills with water under in-situ hydrostatic pressure with no aeration. A check valve at the base of the sample reservoir then closes, preventing the escape of the sample as the probe is removed from the ground. The sample is then transferred to the appropriate sample containers. The HydroPunch® contains several limitations including:

- Five feet of hydrostatic head above the sampling port is required to fill the probe;
- The probe cannot be pushed through cobbles or thick sequences of coarse, gravelly material;

- The probe does not always open or fill, and the check valve does not always close properly;
- A limited volume (500 milliliters) of ground water can be collected;
- The technique does not provide for a permanent monitoring point;
- Soil samples cannot be collected for logging or chemical characterization.

Packer Assemblages

The packer assembly is a device used to isolate and sample a discrete interval in the subsurface. The packer assembly consists of a steel tube equipped with one or two inflatable balloon like units (packers) located above and below the sampling port. Hydraulic or pneumatic-activated packers are wedged against the casing wall or screen allowing for sample collection from an isolated portion of the well. The packers are deflated for vertical movement within the well and inflate when the desired depth is reached. Packers are usually constructed from some type of rubber or rubber compound and can be used with submersible, gas-lift, and suction pumps.

The packer assembly allows for sampling of low-yield wells, and wells that would otherwise produce turbid samples. Disadvantages include the potential for vertical movement of water outside the well, depending upon the pumping rate and formation properties. In addition, the packer materials may be chemically reactive, causing gain or loss of organic contaminants through sorption or desorption.

Sample Containers

Sample containers should be selected based upon the analytical parameters to be performed. Sample container selection and laboratory cleaning procedures are discussed in TechLaw's U.S. EPA-approved Quality Assurance Project Plan for U.S. EPA-client projects or, as appropriate, in SW-846. Clean sample containers should be sealed and stored in a clean environment to prevent any accumulation of dust or other contaminants. To minimize the possibility of volatilization of organic constituents, no headspace should exist in the containers of samples containing volatile organics. Immediately after the samples designated for volatile organics analysis have been filled and capped, they should be checked for headspace. If headspace is observed, the sample should be recollected in it entirety as the containers should not be "topped off" to fill additional headspace.

If this SOP is used to accommodate split samples at the request of the client, the groundwater samples should be split by alternately pouring the aliquots from the sampling device into each container receiving the split sample until the containers are full. This method is appropriate for all analyses except volatile organics. When splitting for volatile organics analysis, each VOA container should be completely filled (with no headspace) and sealed; vials should not be kept open while the sample is distributed between vials.

Miscellaneous Equipment

As part of the process of groundwater sampling, ancillary/miscellaneous equipment may be required to accomplish these activities in the most appropriate, and quality assured manner. The list of the following equipment, in addition to the sampling equipment discussed above, should be prepared in advance of entering the field for the sampling activities. The following list may not necessarily comprise a complete list of items that should be brought to the field for the sampling activity. Additional items may be necessary, and should be determined on a case by case basis.

- Adequate supply of sampling containers
- Adequate storage/transport capacity (i.e., coolers, transport boxes, etc.)
- Adequate volume of ice for cooling samples during the sampling event, following the sampling event, and if applicable, during shipment to the laboratory.
- Adequate quantities of sampling paperwork (i.e., chain-of-custody forms, sample labels, sample tags, custody seals, shipping labels/declarations, transport stickers, etc.)
- Spill/contamination control materials (i.e., plastic sheeting, extra sampling devices, buckets, deionized water, alconox/liquinox, foil wrap, ziploc bags, etc.)
- Water level indicator, field monitoring equipment for both water quality parameters and health and safety monitoring.

Sample Collection Procedures

Sample Collection

Sample Collection From Bailers

- Complete all pre-sampling activities, refer to SOP No. 06-03-XX (e.g., collection of water level elevation data, well purging activities, determination of water quality parameters). Commence sampling only after the wells have sufficiently recharged from the well purging activities.

- Attach a clean length of nylon coated string/rope or other cable to the bailer. The bailer and rope/string/cable must not be allowed to touch the ground or other surfaces during sampling to prevent cross contamination..

- Lower the bailer slowly and gently into the well so that agitation of the water column is minimized. Allow the bailer to fill completely with groundwater but do not allow the bailer to touch the bottom of the well. Slowly retrieve the bailer. If the proposed groundwater analysis does not include volatile organic compounds, rinse the bailer completely with this volume of water (not required unless changing bailers) and discard into a purge water storage container (e.g., 5 gallon bucket, steel drum or other). However, this step should not be performed if the analytes of interest include VOCs.

- Fill the sampling containers in the order presented in the section below on analyte collection order.

<u>Pumps, Packer Assemblages, and other Sampling Devices:</u>

Initiate sampling activities following the pre-sampling activities as directed for the use of Bailers. Allow the groundwater to discharge into a pre-determined collection vessel (i.e., , tank, 5-gallon bucket, steel drum or other) for several minutes to allow the device and tubing to purge. Check the sample indicator parameters (i.e., pH, temperature, and specific conductance) while the device and tubing are being purged. Depending upon the nature of the aquifer, the sample flow rate, or the analytical field parameters measured, the purging should continue until successive readings are stabilized to within approximately 10 percent of the previous reading. Alternatively, if the field parameters do not stabilize over time, following the evacuation of at least three well volumes, the field personnel may decide to discontinue the purging activities and initiate sample collection. Once the sample collection activities are initiated, samples should be collected in the order presented in the section below on analyte collection order.

<u>Analyte Collection Order</u>

Sample containers should be filled according to the volatility of the target analytes. The preferred collection order for some common groundwater parameters follows:

- Volatile organics (VOA)
- Purgeable organic carbon (POC)
- Purgeable organic halogens (POX)
- Total organic halogens (TOX)
- Total organic carbon (TOC)
- Extractable organics
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionuclides

Filtering Sample Aliquots for Inorganics

Sample fractions for dissolved metals should be filtered in the field prior to preservation. Samples for analyses other than dissolved metals will not be filtered. The sample alliquot should be passed through a disposable 0.45 micro meter filter prior to transferring the sample material to the appropriate sample container. Dispose of the filter and record the filtration on the sampling label/tag and field logbook. Mark the Chain-Of-Custody Record to indicate that dissolved metals analyses are required.

Sample Preservation

Once the sample collection activities are complete, the samples will be preserved to ensure the integrity of the samples while in transit to the analytical laboratory. Specifically, samples are preserved to retard biological action, retard chemical reactions such as hydrolysis or oxidation, and reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and protection from light.

Specific procedures for packaging sample preservatives are contained in SOP Section Nos. 04-01-XX.

Sample Labeling

To ensure proper identification and tracking of samples, each sample collected should be labeled by completing and affixing sample identification labels or tags. See SOP No. 02-05-XX and Series 04 for additional instruction.

Chain-Of-Custody and Records Management

The Chain-Of-Custody procedure allows for the reconstruction of how and under what circumstances a sample was collected, including any problems encountered. If properly followed, the procedure prevents the misidentification of samples, prevents tampering with the samples during shipment and storage, allows for easy identification of any tampering, and allows for the easy tracking of possession. Items to be completed as part of the Chain-Of-Custody procedure includes sample labels and/or sample tags, custody seals, and the Chain-Of-Custody Record. The procedure for completing these items are contained in SOP No. 02-05-00.

Documentation and Records

A permanent record must be maintained for all sampling activities. Usually, this permanent record is the field logbook. Field documentation of groundwater sampling activities is also required where personnel are conducting field oversight of other contractors on behalf of the EPA or other state agencies. Photographs should also be taken to document the groundwater sampling activities. In addition to the items described in SOP Series 03, the record/logbook must include, but not be limited to, the following items:

- Time and date of sampling activities;
- Well identification, location, type (e.g., monitoring wells, piezometers, etc.);
- General condition of the well, well construction (e.g., PVC, stainless steel);
- Total well depth and diameter;
- Well screen interval depths;
- Static water level depth and measurement technique;
- Sample collection procedure and equipment;
- Whether split samples were collected (e.g., for the facility, EPA, or state agencies);
- Any deviations from the groundwater sampling and analysis plan (e.g., deviations in the type of equipment used, cleaning procedures, well evacuation techniques, packaging and shipping procedures, and sample collection/preservation/handling procedures);

Health and Safety Section

It is TechLaw's policy to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress which is consistent with OSHA and other applicable and appropriate established standards and requirements.

All field personnel will be provided with appropriate protective clothing and safety equipment. At a minimum, this will include steel-toed shoes, safety glasses, hard hat, and chemical-resistant gloves.

A site-specific health and safety checklist/plan must be developed by the Field Team Leader or designee and approved by the TechLaw Health and Safety Director prior to implementation in the field. This checklist/plan must be reviewed prior to beginning work.

Any deviation(s) from an approved site-specific health and safety checklist/plan must be documented in the field logbook.

QA/QC Section

In addition to adhering to the specific requirements of this protocol and any supplementary site-specific procedures, the QA/QC requirements for this activity should be clearly defined in the Sampling and Analysis Plan and developed in compliance with procedures outlined in SOPs in the 11-XX-XX series.

Comments/Notes

None at this time.

Attachments

None at this time.

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Technical Approval: ______________________ Date: 6/15/99

QA Management Approval: ______________________ Date: 6/21/99

SOP Description

This Standard Operating Procedure (SOP) describes four types of well abandonment methods and establishes the procedures to be used by TechLaw staff involved in the abandonment of groundwater monitoring wells and piezometers. TechLaw staff may participate in performing, overseeing, or supervising the abandonment of groundwater monitoring wells and piezometers for government or commercial clients. Wells must be abandoned in a manner to prevent the migration of contaminants from the ground surface to the water table or between aquifers. Usually, this involves completely removing the well casing and cleaning out the borehole, then backfilling the borehole with a cement/bentonite grout.

General Procedures

Related SOPs

This SOP is to be used in conjunction with the other relevant or applicable SOPs found in the following SOP categories.

Section No.	Section Title
01	General Procedures
02	Field Procedures
03	Field Documentation Procedures
04	Packaging and Shipping Procedures
05	Field Equipment Operation and Maintenance Procedures
06	Groundwater Sampling/Monitoring and Analysis Procedures
09	Health and Safety Procedures
10	Regulatory Compliance Procedures
11	Quality Assurance Procedures

Related Documentation

The following documents should be used in conjunction with this SOP regarding the abandonment of groundwater monitoring wells and piezometers.

- Field logbook
- Well log(s) and well construction diagram(s)
- Health and safety plan
- Relevant facility/site information

Well Abandonment Methods and Procedures

Groundwater monitoring wells and piezometers that are no longer required as part of a groundwater monitoring system must be abandoned in a manner to prevent the potential migration of contaminants from the ground surface to the water table, or between aquifers. Proper abandonment of wells may also be required to eliminate physical hazards and/or to conserve aquifer yield and hydrostatic head. Four different well abandonment procedures are described. Although a drilling company is usually contracted to perform the actual abandonment activities, TechLaw personnel must direct and oversee the physical operations. The steps which must be accomplished for each well abandonment method are listed below. The four methods are: (1) overdrilling and pulling the casing from the borehole; (2) pulling the casing from the borehole; (3) reaming the casing; and (4) cementing the casing in-place. The TechLaw representative responsible for directing and overseeing the well abandonment activities must select the proper abandonment method based upon the site-specific geology and well construction details for each monitoring well.

Overdrilling and Pulling the Casing

Overdrilling and pulling the casing is the most commonly used method of well abandonment, and can be performed on small-diameter monitoring wells and piezometers generally less than 4 inches in diameter.

- Set the drilling rig directly over the well to be abandoned.

- Drill around (overdrill) the existing well casing with an oversized hollow-stem auger to the bottom (total depth) of the well. The hollow-stem auger diameter must be large enough to surround both the existing well casing and the annular space fill material (e.g., grout, bentonite seal, and well screen filter pack).

- Attach a wire cable (or drill rods if appropriate) to the existing well casing and pull the casing and attached cemented annular space material from the ground through the hollow-stem auger. The hollow-stem auger must remain fixed and secure in the ground while the casing is being lifted to ensure the wellbore remains open and intact.

- If well materials (e.g., cement/grout, bentonite, sand pack) remain in the bottom of the borehole after the well casing has been removed, lower a smaller-diameter hollow-stem or solid core auger through the center of the larger hollow-stem auger to drill out and lift any remaining well materials to the surface.

- Remove the smaller diameter auger and backfill the borehole by lowering a tremie pipe through the center of the hollow-stem auger to the bottom of the borehole and pressure-grouting with bentonite/cement grout from the bottom of the well to the surface. During the backfilling (grouting) procedure, slowly raise the hollow-stem auger to the surface and remove it from the borehole. After the hollow-stem auger has been removed and the borehole has been filled, remove the tremie pipe from the borehole.

- Allow the cement/bentonite grout mixture to set for a minimum of 24 hours. Note: cement/bentonite grout mixtures normally settle during the curing process and the upper surface of the mixture may drop several feet below the ground surface. Refill and check any depressions until the cement/bentonite grout mixture is within two feet of the ground surface or the frostline, whichever is deeper.

- After the grout has set, pour a concrete surface seal (plug) into the top of the borehole until the seal is flush with the ground surface.

- Decontaminate (refer to SOP No. 02-03-XX) all casings, screens, or other materials removed from the abandoned well. Test for contamination (e.g., use wipe test or test rinsate from decontamination) and dispose of accordingly. See SOP No. 02-04-XX, Management of Investigative Derived Wastes, for further details.

Pulling the Casing

Monitoring wells and piezometers which are too large in diameter to be removed by overdrilling may be abandoned by pulling the casing from the ground. This procedure should only be performed for wells completed in consolidated materials, where the borehole will remain open after the casing has been removed. Well abandonment by pulling the casing works best in wells and piezometers with little annular grout or where the grout is in good (competent) condition and is securely cemented to the casing materials.

- Set the drilling rig directly over the well to be abandoned.

- Emplace a solid stem auger or drill stem attached with a tapered-wedge head assembly into the upper portion of the existing casing. Ensure that the auger is firmly attached to the casing by pulling on the casing a few times.

- Pull the casing and attached cemented annular space material from the ground by lifting the auger/drill stem with the drilling rig. As the casing is lifted from the ground, cut off sections so that the remaining (below ground) portions of the casing can be lifted. Care must be taken to prevent the casing from breaking or twisting off below the ground surface. If this happens and the remaining casing cannot be retrieved, the remaining portions of the casing may have to be cemented in-place.

- After the casing and annular space material has been removed from the borehole, ream (drill out) the open borehole with a solid stem auger or roller cone bit to remove the remaining grout and filter pack material.

- Backfill the open borehole by lowering a tremie pipe to the bottom of the borehole and pressure grouting with bentonite/cement grout from the bottom of the well to the surface. Slowly retract the tremie pipe as the grout level rises within the borehole. When the grout mixture reaches the ground surface, completely remove the tremie pipe from the borehole.

- Allow the cement/bentonite grout mixture to set for a minimum of 24 hours. Note: cement/bentonite grout mixtures normally settle during the curing process and the upper surface of the mixture may drop several feet below the ground surface. Refill and check any depressions until the cement/bentonite grout mixture is within two feet of the ground surface or the frostline, whichever is deeper.

- After the grout has set, pour a concrete surface seal (plug) into the top of the borehole until the seal is flush with the ground surface.

- Decontaminate (refer to SOP No. 02-03-XX) all casings, screens, or other materials removed from the abandoned well. Test for contamination (e.g., use wipe test or test rinsate from decontamination) and dispose of accordingly. See SOP No. 02-04-XX, Management of Investigative Derived Wastes, for further details.

Reaming the Casing

Wells and piezometers that cannot be abandoned by the previously listed techniques can be abandoned by reaming, or "drilling out" the casing.

- Set the drilling rig directly over the well to be abandoned.

- Attach a drag bit, roller cone bit, or solid stem auger equipped with a carbide cutting head to the drill stem and grind the casing into small cuttings.

- Flush the cuttings from borehole with potable water. Drilling muds may also be used to flush the cuttings if approved by the regulatory agencies.

- Ream the borehole with a larger diameter bit to remove any remaining annular space materials (e.g., grout or filter pack materials) from the borehole.

- Backfill the open borehole by lowering a tremie pipe to the bottom of the borehole and pressure grouting with bentonite/cement grout from the bottom of the well to the surface. Slowly retract the tremie pipe as the grout level rises within the borehole. When the grout mixture reaches the ground surface, completely remove the tremie pipe from the borehole.

- Allow the cement/bentonite/cement grout mixture to set for a minimum of 24 hours. Note: cement/bentonite grout mixtures normally settle during the curing process and the upper surface of the mixture may drop several feet below the ground surface.

Refill and check any depressions until the cement/bentonite grout mixture is within two feet of the ground surface or the frostline, whichever is deeper.

- After the grout has set, pour a concrete surface seal (plug) into the top of the borehole until the seal is flush with the ground surface.

- Decontaminate (refer to SOP No. 02-03-XX) all casings, screens, or other materials removed from the abandoned well. Test for contamination (e.g., use wipe test or test rinsate from decontamination) and dispose of accordingly. See SOP No. 02-04-XX, Management of Investigative Derived Wastes, for further details.

Cementing the Casing In-Place

Wells should be cemented in place when abandonment cannot be accomplished by any of the above-listed procedures. This well abandonment technique is the least preferred method because the well casing and annular space materials are left in the borehole. Cracks and voids in the annular grout behind the well casing can serve as conduits for contaminant migration between different aquifers and the ground surface.

- Set the drilling rig directly over the well to be abandoned.

- Lower a tremie pipe to the bottom of the well through the center of the well casing. Pressure-grout the well with a bentonite/cement grout from the bottom of the well to the surface. Slowly retract the tremie pipe as the grout level rises within the borehole. When the grout mixture reaches the ground surface, completely remove the tremie pipe from the borehole.

- Allow the cement/bentonite grout mixture to set for a minimum of 24 hours. Note: cement/bentonite grout mixtures normally settle during the curing process and the upper surface of the mixture may drop several feet below the ground surface. Refill and check any depressions until the cement/bentonite grout mixture is within two feet of the ground surface or the frostline, whichever is deeper.

- Cut off any excess casing extending above the ground surface. The remaining in-ground casing should be flush with, or below the ground surface.

- Cover the remaining casing and borehole with a concrete surface seal (plug). The concrete seal should also be set flush with the ground surface.

- Decontaminate (refer to SOP No. 02-03-XX) all casings, screens, or other materials removed from the abandoned well. Test for contamination (e.g., use wipe test or test rinsate from decontamination) and dispose of accordingly. See SOP No. 02-04-XX, Management of Investigative Derived Wastes, for further details.

The well abandonment techniques described above are to be used for low complexity hydrogeologic terrains. In more complex hydrogeologic environments (e.g., cavernous karst completions, high pressure artesian aquifers), different well abandonment techniques that are not discussed in this SOP should be considered for use. Additional information concerning abandonment in these situations is contained in the references listed at the end of this SOP. In particular, refer to the American Water Works Association (1984) and the National Water Well Association (1989) references. Furthermore, Hurlburt (1990) discusses the abandonment procedures for potable water wells in selected southern and southwestern states.

Documentation and Records

A permanent record must be maintained for each monitoring well abandoned. Usually, this permanent record is the field logbook; however, many states also require that well abandonment completion reports be filed with the appropriate state agencies. Field documentation of well abandonment procedures is also required where personnel are conducting field oversight of other contractors on behalf of the EPA or state agencies. Photographs should also be taken to document the well abandonment procedures used in the field. The record/logbook must include, but not be limited to, the following items:

- Time and date of well abandonment activities;

- Personnel performing the well abandonment activities;

- General weather conditions at the time of the well abandonment;

- Well identification number and location;

- Initial borehole and well casing/screen diameters;

- Type of well casing in the borehole;
- Type of equipment used to remove the well casing and screen from the borehole;
- Total depth and diameter of new borehole (if the casing is overdrilled or the old borehole is reamed);
- Any problems encountered in the removal of the well casing and/or screen (if grouted with portions of the well casing remaining in the borehole);
- Type and volume of backfill/sealant material used (i.e., cement/bentonite grout, concrete, native soils);
- Measurement of the concrete plug; and
- Type of permanent marker installed, if applicable.

Health and Safety Section

It is TechLaw's policy to maintain an effective program for control of employee exposure to chemical, radiological, and physical stress which is consistent with OSHA and other applicable and appropriate established standards and requirements.

All field personnel will be provided with appropriate personal protective clothing and safety equipment. At a minimum, this will include a hard-hat, hearing protection, full-face respirator, steel-toed safety shoes, and safety glasses. Personnel are required to inspect their PPE prior to entering any job site and replace any damaged items.

A site-specific health and safety checklist/plan must be developed by the field team leader or designee and approved by the TechLaw Health and Safety Director prior to implementation in the field. This checklist/plan must be reviewed with the TechLaw field team members prior to beginning work.

Any deviation(s) from an approved site-specific health and safety checklist/plan must be documented in the field logbook.

QA/QC Section

The field team leader or designee is to conduct periodic reviews of the field logbook and copies of the forms utilized to ensure that the documentation procedures and administrative requirements have been met.

Comments/Notes

None at this time.

Attachments

None at this time.

References

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